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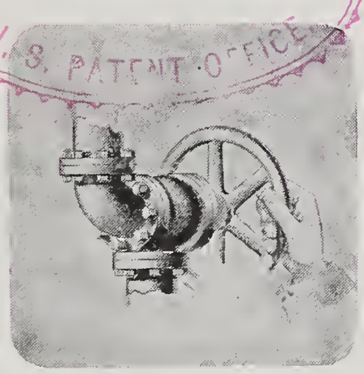

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INDEX

TO

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VOLUME II.

GEORGE I. ALDEN.

CASSIER'S MAGAZINE.

VOL. II. MAY, 1892. No. 7.

THE SPEED-REGULATION OF CENTRAL STATION ENGINES.

By William S. Aldrich, M.E.

THE necessity for uniform speed in steam-engines driving electric lighting dynamos has developed a high class of speed, regulating mechanisms chiefly of the centrifugal governor type. It is *claimed* that the best of these, among the automatic cut-off shaft governors, will regulate the speed of the steam-engine within one-half of one per cent. under extreme variations of load, but constant steam pressure. A standard type of this class of engines had its governor very carefully "nursed" by a skilled mechanic from the engine works, and ran at 286½ revolutions under almost no load and 284 revolutions under normal working load.

Alternating-current work, especially in its coming field for the transmission and distribution of power, calls for the most exact regulation of speed of the engine and dynamo, particularly with synchronizing motion. Here the demand is somewhat imperative. Mr. William Stanley, Jr., has pointed out, in a paper before the Fifteenth Convention of the National Electric Light Association, Buffalo, February 23, 1892, on "Alternate Current Motors," that "it is necessary that the speed of the dynamo should remain constant; as constant as possible. If the stations will give us a definite number of alternations, and will maintain that number, our motors will behave beautifully."

The extreme subdivision of the central station power into many small units, supplying small units of load on the external circuit of the dynamo has been to the advantage of the engine and dynamo builders and the comfort of the people using the lights; for the best centrifugal governing has, apparently, done well enough in keeping the speed of the engine within very small limits of variation, and the lights reasonably steady.

The dynamos have usually been of small units, from 25 to 150 horse-power for incandescent lighting (though these are rapidly increasing in size for extended municipal service), and about 50 horse-power for arc-lighting. Being flexibly connected to the engine-pulley by direct belting, or through countershafting, the small variations of load caused by throwing in or out a few lamps had to be transmitted to the valve mechanism through altered belt-tensions. Though tardy in its operation compared to the instantaneous changes of load on the external circuit of the dynamo, this feature is said to be a decided advantage by the adherents of belt transmission. In addition to this, an actual change of speed is required to operate the governor's fly-weights, and so change the steam-supply more or less proportional to the load, if it were possible to do so by this means. A 60 horse-power automatic cut-off engine, centrifugal shaft governor, has been known to pick up its speed in 5 revolutions (running 300 revolutions per minute) after throwing on 40 horse-power at the switchboard-

engine directly belted to dynamo. The units of power thrown on and off the dynamo circuit have usually been, in the lighting service, only a few tenths of a horse-power each,—arc lamp, about 0.8 horse-power and incandescent lamp about 0.1 horse-power. Very few, even of these, are cut out after the regular lighting service has begun; so that, for the first stages of central station development, the centrifugal governor has controlled the engine speed more or less satisfactorily, under the very small percentage of load variations produced by throwing on or off a few lamps.

The installation of large units for both dynamo and steam-engine, with the greatly increased economy in the use of steam that comes of concentration and direct connection, presents new problems in engine governing. *The Electrician* (London) believes that central station-engine units should be 300 horse-power, for best steam economy and subdivision in case of breakdown. The new Edison Central Station, at Pearl and Elm streets, New York city, will have its first installation of 1500 horse-power units, and additions of 4000 or 5000 horse-power engine units.

The multiple expansion steam-engines of the marine type, coupled direct, or directly belted to multipolar dynamos, bring problems to the front in speed regulation that have not been very successfully solved in the case of engines of the same power in the marine service. The speeds are slightly greater in the smaller units of 300 to 1000 horse-power; from about 35 to 100 in the marine engine at sea, to about 75 to 200 in the marine engine at the central station—less speed for the greater powers.

Marine engines require, at sea, no special regulation of speed; and the only governing that is more or less a necessity is, to prevent "racing" in heavy seas, and in violent pitchings. This has been met by special forms of disconnective centrifugal governors, or by hydrostatic governors, actuated by the varying depth of immersion of the propeller. But the marine type of steam-engine in central station service for electric-lighting power or railway work has at least come to stay, bringing with it difficult problems of regulation to suit the exacting requirements of its new environment.

The electric railway (at present in the street-car service), and the electric distribution of power in large and small machine shops, and other manufacturing and industrial establishments, throw on and off larger units of power than in the lighting service. Several motors are quite likely to be thrown into or out of the line circuit at one time.

All street-cars are starting or stopping every few minutes, sometimes seconds, so that these incessant variations of load, and the large units of power that are thrown on and off the dynamo circuit make the speed regulation of the steam-engine far more difficult than in the lighting service, yet quite as necessary.

Taking the ordinary street-car unit at from 15 to 40 horse-power, at starting, it represents a larger per cent. variation in an ordinary 500 horse-power engine and dynamo plant (a comparatively small plant unit), than throwing on an arc lamp, and very much more than for an incandescent lamp unit. These 15 to 40 horse-power units, or more, are not a small per cent. of the dead load of the system, as is the case of a steam-engine driving a cable plant; for, in this latter, there is still left the dead load of all the transmission and cable machinery of the system after all the cars are off. But all the cars off the circuit, in the electrical system, would leave little else than the steam-engine friction, and the journal, air, and magnetic friction of the dynamo as a dead load.

Moreover, this percentage of load variation, on throwing on or off a street-car, under light or normal load conditions, would be felt almost instantly at the engine, while, in the cable system, it would have to travel along the cable in a series of ever-weakening impulses to the engine-pulley. Therefore, centrifugal governing may be quite satisfactory in a cable system, where the load-changes produce smaller percentages of variation above the comparatively large and constant dead load. It is almost out of place in the electrical system, with its larger percentages of load changes

above a comparatively small and constant dead load.

Variations in the external circuit of the dynamo are immediately and positively felt at the engine, in direct connection, and in a way requiring an instantaneous adjustment of the steam supply in order to maintain reasonably uniform speed. Rolling-mill engines are subject to greater extreme variation than those in the ordinary electric railway service. But such continuous regularity of speed is not required in the former as in the latter.

The speed of engines is ordinarily controlled by varying the mean effective pressure on the piston, in a way that will correspond in some degree to the change of load on the driving-pulley. But this mean effective pressure does not vary in the form of any simple function of the external load, nor direct proportional relation,—whether it be brought about by a change in the initial pressure (as by throttling governors), or a change in the rate of its expansion in the cylinder (as by automatic cut-off governors), nor yet by any simple change in both of these, even if such were desirable.

During the expansion of the steam in the cylinder, no regulation is possible. This feature becomes more important for high powers and low speeds than for low powers and high speeds and for single cylinder engines than those of the multiple expansion type. In either case the steadying action of the fly-wheel will serve as an additional advantage—more for the former than the latter type.

In throttling engines, a continuous change in the steam supply may be effected up to the fixed point of cut-off by load changes. In the automatic cut-off engines with slide-valve mechanisms,—a change in the load effecting a change in speed, position of governor's fly-weights and consequent alteration of the valve-mechanism will be inoperative in changing the steam supply after the point of cut-off; but it will alter the point of exhaust opening, the point of exhaust-closing (if no change occurs during exhaust), and usually the admision in the next stroke as well as the return-stroke. There the mean effective pressure is made up of variable mean forward and back pressure, in the Corliss types the point of cut-off alone being varied by the tripping of the valves by the governing mechanism. The mean effective pressure is made up of variable mean forward pressure, and usually constant mean back pressure, and any change in the load, speed, and position of the governing mechanism is not usually felt till the next stroke or the return-stroke.

These inherent difficulties in steam-engine regulation, arising from an intermittent supply of the steam, and further increased by the combined effect of several others, more or less beyond control, such as the initial condensation and final re-evaporation of the steam, its quality (percentage of entrained moist ture), and the percentage of clearance in variable expansion engines. Again, all of these combined, inherent defects are usually much more appreciable in large, slow-speed engines than in small, high-speed ones, increasing still further the difficulty of governing the marine engine on shore in the electrical service.

The indicated horse-power variations, under assumed constant speed, are proportional to the mean effective pressure variations. But it does not follow that uniform speed will follow from making the mean effective pressure proportional to the external load, even if it were possible to do so, for the engine friction is almost a constant quantity under ordinary load changes and constant speed. However, the more nearly these conditions are approached in practice, the closer will be the regulation.

The governing forces called into operation to control the steam supply have been almost altogether those brought about by a slight change in the speed of revolving weights, whose centrifugal force is opposed by gravity or tension springs. Either an alteration in the position of the throttle or of the cut-off mechanism may be effected by the effort of the fly-weights to regain a position normal for that speed of the engine for which they have been set. But the centrifugal governing principle possesses many well-known defects, even in the best automatic cut-off shaft-governors, such as requiring a change of speed to regulate against a change of

speed, not holding the engine at the normal speed when it is attained, on account of the instability of the equilibrium on the centrifugal and centripetal force; which instability is but increased by finer adjustments of tension springs, etc., on account of the isochronal action of the fly-weights. This leads to over-sensitiveness and "bursting," requiring careful and skillful "nursing" to hold the governor up to its best work.

Load, or dynamometric governing, alone, has not proven successful. Weisbach, in his *Mechanics of Engineering*, has pointed out its essential defect, in considering the Poncelet governor (a spring transmission dynamometer), namely, "of exerting a [the desired] regulating effect only when there is a variation of resistance and not when there is a variation of driving force." Though this has less weight to-day, when we are supposed to keep the boiler pressure constant (or nearly so), still it is an inherent objection; and, even if the driving force on the piston were absolutely constant, the characteristic mechanism of the crank and connecting-rod of the steam-engine prevents the crank effort being at all constant. If the resisting movement of the external load, as applied at the rim of the driving-pulley of the transmission dynamometer, is assured uniform, even then the springs of the dynamometer (through which the load is transmitted) will be unequally strained, owing to the variable crank efforts at different parts of the stroke of the (supposed) uniformly driven piston. So that, under the most favorable conditions of uniform driving effort on the piston and uniform resisting movement on the driving-pulley, it does not follow that the spring or other mechanism of the transmission dynamometer will so uniformly operate the valve mechanism as to give a steam supply proportion to the external load.

The combination of centrifugal and load governing forces, both operating conjointly upon the mechanism of a single slide-valve, has been worked out in the Ball load-governor. This has come very near the mark in point of close-speed regulation, as shown by repeated trials with the Moserop speed-recorder, when extreme variations of load were transmitted through the springs of the dynamometer governor-pulley.

Electrically controlling the throttle by an electro-magnetic mechanism under the action of the dynamo current, as suggested by Sylvanus P. Thompson in his work on *Dynamo-Electro Machinery*, has been followed by many special forms of electric governors. They have been chiefly for the arc lighting service, though a modification of the windings and connections, of course, adapt them equally well to the incandescent service. The usual operation of these electric throttling governors, placed on engines otherwise operated by slide-valves moved by fixed eccentrics, is to slow down the engine when the arc lamps were cut out one or more at a time. Cutting out all the lights slows the engine down till it just turns over sufficiently to keep it going to overcome its own and the dynamo friction, and keeps the electro-magnetic mechanism of the governor and the dynamo fields just about charged up to the constant current of the circuit. Throwing in the lights increases the engine speed, to maintain constant current, till it reaches its normal speed when the ordinary lighting service is in circuit. But such slowing down of the engine under load variations would be extremely detrimental, especially in the case of large engines.

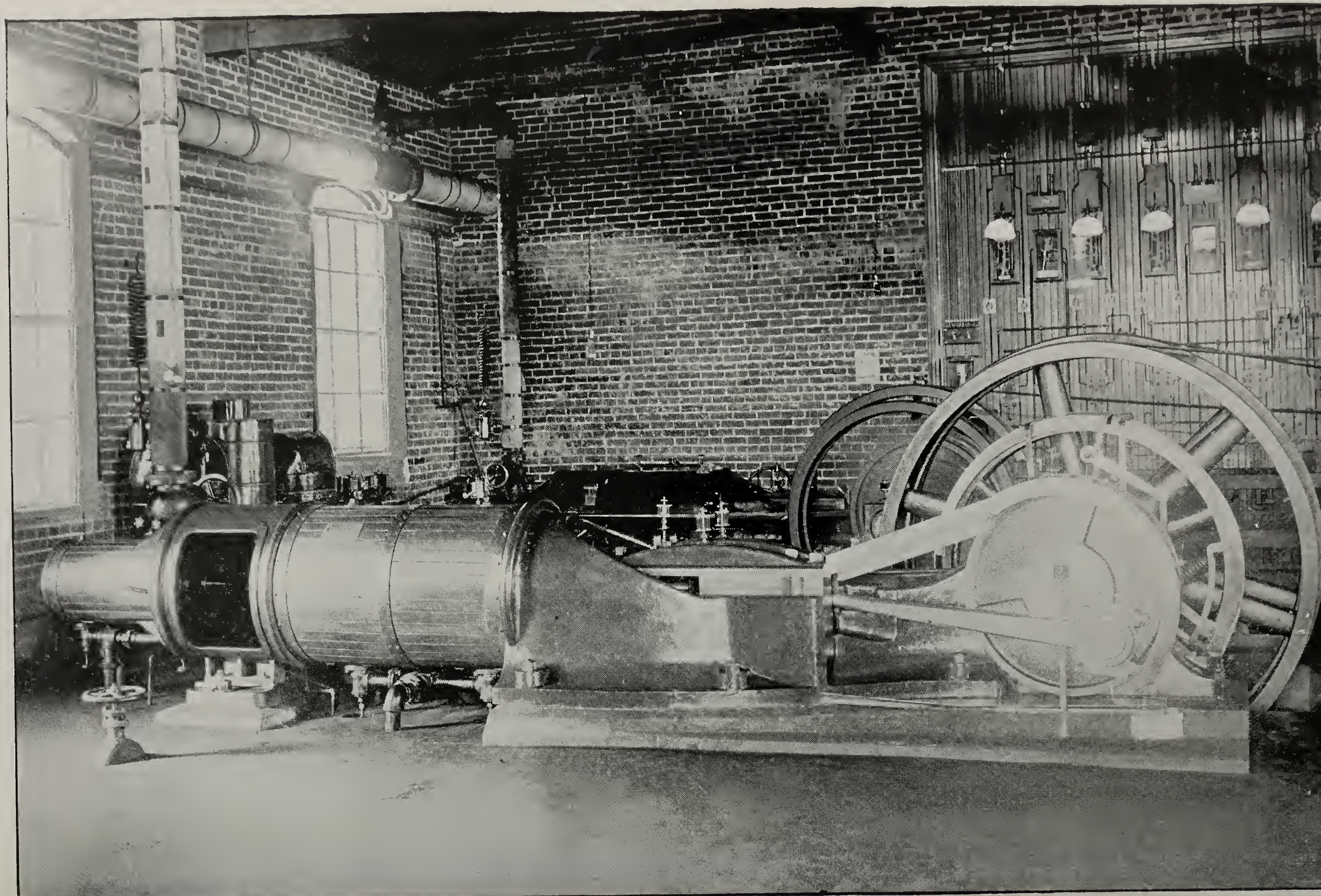
Differential electric governors have been arranged (as in the Williams type), operating in such a way that the electro-motive force of the dynamo is opposed, through the electro-magnetic governing mechanism, to a constant electro-motive force, as that of a storage battery. The engine is thus governed against any change of the *difference* of potential between the dynamo and the storage battery.

When this comparative study of the present methods of governing steam-engines for electric lighting and power service, and the indications of still further developments in the use of vertical inverted multiple-expansion engines of the marine type, from 500 horse-power and up, using steam from 150 pounds up, and running at speeds of from 75 to 200 revolutions per minute,—directly coupled to the multipolar dynamos (or

driving by belting in special cases),—it would seem that the next step should be taken in the direction of controlling the point of cut-off by an electro-magnetic governing mechanism, under control of the circuits of the dynamos driven by the engine, and the action of which governing mechanism upon the variable expansion valve mechanism of the engine should be in conjunction with, or more or less independent of, a further control of the same valve mechanism by a standard centrifugal governor. This combines the centrifugal and load—governing principles in such a way as may seem most desirable and best suited to the engine in hand, and as meeting the demands upon the same in the electrical service.

Electro-magnetic centrifugal governing may be applied to equal advantage for the regulation of prime movers in other fields than the electrical, as well as to all classes of prime movers in that particular field. An electro-magnetic mechanism, at the point of application of the power delivered by the prime mover, will develop a current proportional to the power called for; which current, being used to operate a similar electro-magnetic mechanism at the engine, will control the steam-supply, for instance, more or less in proportion to the external load variations. Thus, dynamometric or load governing becomes easily possible when considerable distance intervenes between the prime mover and the point of application of the power delivered. The two electro-magnetic mechanisims, involved in the governing, may be a foot apart, or two hundred feet,—the distance apart making no difference in their operation. Cable plants, mill and factory plants, admit of load and centrifugal governing by means of this method of transmitting the load variations through an electro-magnetic mechanism.

The many special problems at once brought forward in this new method of electro-magnetically and centrifugally governing the steam-engines of central stations have been more or less prepared for by the simultaneous development of modern steam-engine practice, on the one hand, and of the rapidly increasing experience in electro-magnetic engineering work on the other hand. These lines of development in the applied sciences of thermo-dynamics and electro-dynamics have already closely met in the modern central station, and they seem destined to be yet more interdependent than ever before, as the great problem is still that of the economical generation of electricity from heat for commercial and industrial purposes.



NEW TANDEM COMPOUND ENGINE. BUILT BY WILLIAM TOD & CO., YOUNGSTOWN, OHIO.
See description, page 67.

A TEST OF MULTI-CYLINDER ENGINES.*

By Samuel M. Green, Holyoke, Mass., and George I. Rockwood, Worcester, Mass., Members A.S.M.E.

IN a recent issue of a technical journal, the theory was advanced by Mr. Rockwood that more than two cylinders in a compound "multi-cylinder" engine were unnecessary to secure the highest theoretical economy in the use of steam. This proposition was severely criticised and declared to be inconsistent with the modern philosophy of the steam-engine. It may, therefore, be interesting to give their attention to an account of a series of tests of a triple-expansion engine, so constructed as to permit "cutting-out of the circuit" the intermediate cylinder, and running the high-pressure and low-pressure cylinders as a two-cylinder compound, using the same conditions of initial steam-pressure and load.

The engine is a triple-expansion, condensing engine, designed by George I. Rockwood for the Merrick Thread Company, Holyoke, Mass., and built by the Wheelock Engine Company, Worcester, Mass. The high-pressure and intermediate cylinders are tandem on one frame, the low-pressure cylinder occupying the right-hand position to an observer standing at the cylinder and looking toward the shaft.

The relative proportions of the cylinders are somewhat novel. As the objects of the designer were to secure an engine of symmetrical appearance, of uniform turning moment at each crank, and of highest attainable steam efficiency, and also to make it possible to run the low-pressure side with high-pressure steam, in case of accident to the high-pressure side, the tandem cylinders were made of shorter stroke than that of the low-pressure cylinder. The high-pressure cylinder was put next to the frame. The exhaust steam from the high-pressure cylinder passes directly into a receiver of the tubular reheater variety, and thence directly into the intermediate cylinder. Another similar receiver lies between the intermediate and low-pressure cylinders. These two receivers are so connected that the ex-

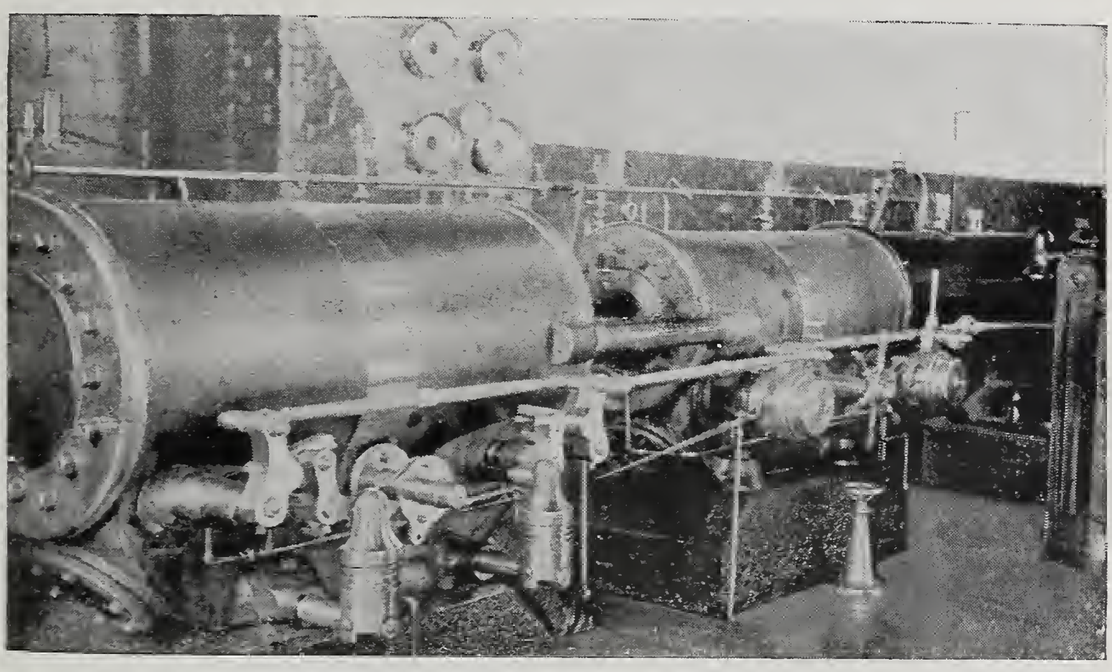


FIG. 185.

* Read at San Francisco meeting of American Society of Mechanical Engineers.

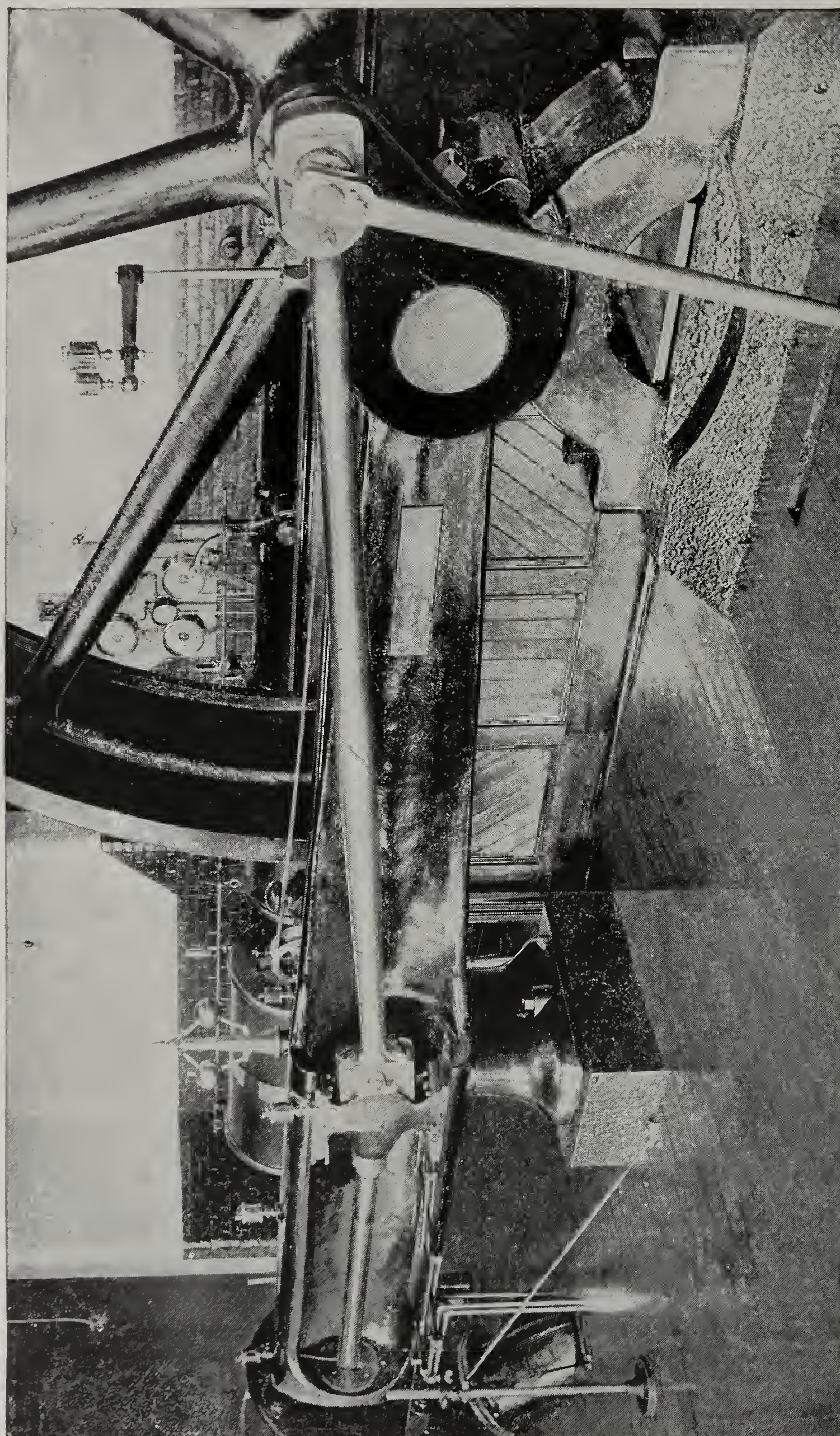


FIG. 186.

haust from the high-pressure cylinder may pass through both into the low-pressure cylinder without going through the intermediate cylinder, the steam and exhaust pipes of which are provided with valves. The first and second cylinders are jacketed on heads and barrels ; the heads only of the low-pressure cylinder are jacketed, and all receiver and cylinder jackets contain steam at full boiler pressure. The cylinder jackets consist of cored spaces. The jacket-drips all collect into one pipe 1½″ in diameter, which discharges into a reservoir, whence it is returned through a steam loop to the boiler, and in no instance are the jackets connected with the cylinder steam-chests.

The valve-gear of the high-pressure cylinder is of a new type, designed to operate gridiron valves under heavy pressures. The valve-gears of the intermediate and low-pressure cylinders are, in all respects, such as have been used heretofore on engines built by the Wheelock Engine Company. The governor operates only upon the cut-off mechanism of the high-pressure cylinder, the releasing gears of the other two cylinders having independent hand adjustments. In case of accident to the high-pressure side of the engine, however, means are provided for connecting the governor with the cut-off mechanism on the low-pressure cylinder.

The engine is located at some distance from the boiler (a Manning upright of 175 rated horse-power), the supply pipe being 325 feet in length. A separator, placed about 10 feet from the engine, collects the entrained and condensed water, which is also returned through the steam loop to the boiler. The condenser is of the jet type, supplied from the canal with injection water, which is removed by a direct-connected air pump.

It was considered unnecessary to make coal measurements, as they have no bearing on the results, but the feed-water was measured in the following manner :

One large tank was employed as a reservoir, from which the feed-pump drew its supply. Above this tank, on a platform, were placed a pair of scales and a small tank which held about 400 pounds of water. (Just before the trials the scales were sealed by the Sealer of Weights and Measures). To the beam of these scales was attached a long pointer. They were accurately balanced with the tank empty, and the position of the pointer was noted and marked. A scale weight of 400 pounds capacity was then placed on the beam, and water was run into the tank until the pointer resumed its balanced position, thus giving just 400 pounds of water in the tank. A small valve was provided in the side of the weighing tank, so that any water which might run in, in excess of the 400 pounds, could be readily withdrawn. A counter was also attached to the tank, so that every filling would be automatically registered independently of the attendant's registration. In this way an accurate account was kept of all the water pumped into the boilers. The boiler feed-pump was connected only with the reservoir and feed-pipe to the boiler used during the tests. Steam for

DIMENSIONS OF ENGINE.

	H.P.	I.	L.P.
Diameter of cylinder	12″	16″	$24\frac{13}{32}$″
" " piston rod	2 and 2¾″	2″	3¼″
Stroke of piston	36″	36″	48″
Clearance in percentage of piston displacement	2%	4%	3%
Inside diameter steam pipe	5″	6″	9″
" " exhaust pipe	6″	7″	10″
Area of steam port	13″	21″	38″
" " exhaust port	16.5″	25″	60″

this pump was taken from other boilers. During the period of testing, the water of condensation from the jackets was not allowed to return to the boilers, but was drained through pipes connected with the lowest points in each of the jackets, each pipe leading down to a separate reservoir provided with gage glass. The discharge pipe, ½-inch in diameter, from each reservoir, was connected with a surface condenser and discharged into a weighing tank. An accurate record was kept of all water drawn from each jacket during each test. A revolution counter indicated accurately the number of revolutions of the engine. Six Tabor indicators were kindly loaned for these tests by the Ashcroft Mfg. Co., of New York. The instruments were all in the best condition and were sent directly from the factory. The manner of attaching the indicators and the pantographs may be seen from the photographs which accompany this paper (Figs. 185 and 186). The springs used in the indicators on the high-pressure and intermediate cylinders were tested under the steam pressure with a steam-gage which had itself just been tested with a mercury column. The springs used in the indicators on the low-pressure cylinder were compared with the mercury column employed instead of a vacuum-gage. The steam-gages were also tested with a test-gage. For determining the quality of the steam after passing through the separator, a Peabody throttling calorimeter was connected with a perforated ½-inch pipe, screwed several inches into the elbow of the steam supply pipe at its point of juncture with the high-pressure cylinder, the connections and calorimeter being thoroughly covered with hair felt.

The following description of the tests will illustrate the manner in which each trial was conducted :

At one o'clock P.M., the engine having been running for fifteen minutes, electric bells were sounded in the engine and boiler rooms, the heights of the water in the boiler and in the lower tank were measured, the reading of the scale counter was noted, the heights of water in the various jacket reservoirs were taken, and the test began.

During the trials, simultaneous indicator diagrams lasting half minute were taken every half-hour, which was considered often enough in view of the exceedingly steady load on the engine ; and pressures and temperatures were carefully noted each time. Every hour the water in the boiler and tank was brought to the heights observed at the time of starting the test, and observations were made for a check on the final result. Just before the time of closing, the boiler pump was stopped, the water in the boiler was allowed to fall below the point of starting, and at precisely six o'clock the bells were sounded, the engine shut down, and steam was shut off from the jackets. The heights of the water in boiler and tank were brought to the same level as at starting.

Three preliminary tests of the engine were thus run, in order to accustom the attendants to their duties. In all the tests made, the reading of the thermome-

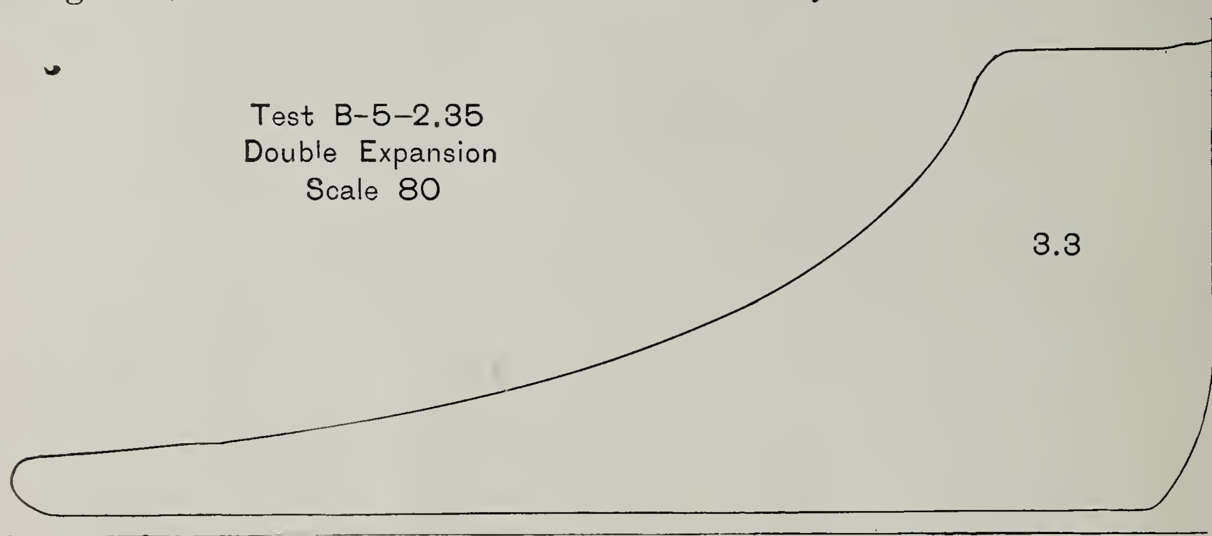


Fig. 175.

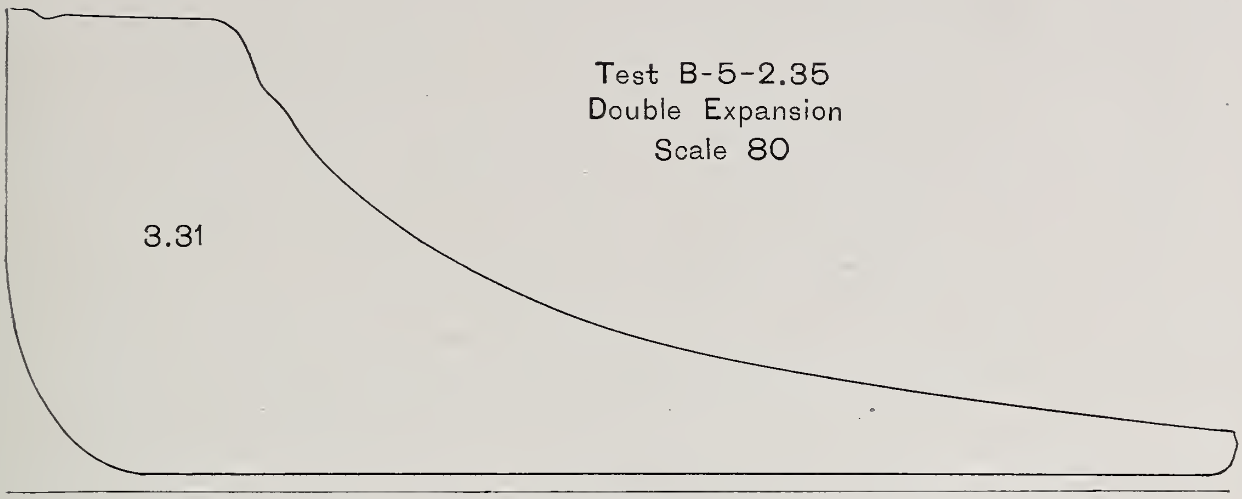


Fig. 176.

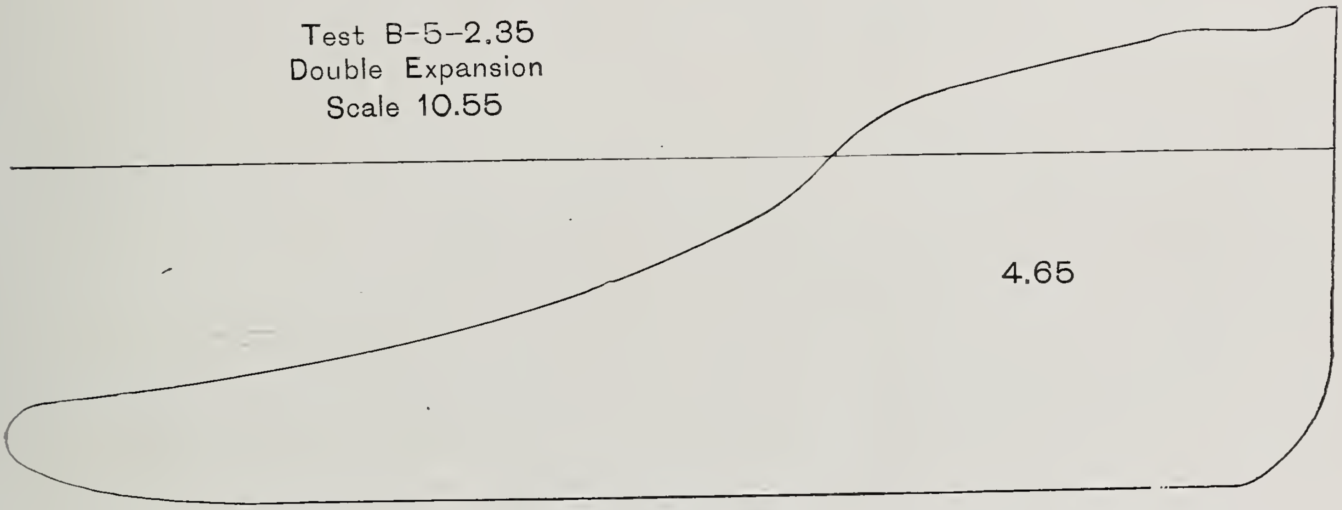


Fig. 177.

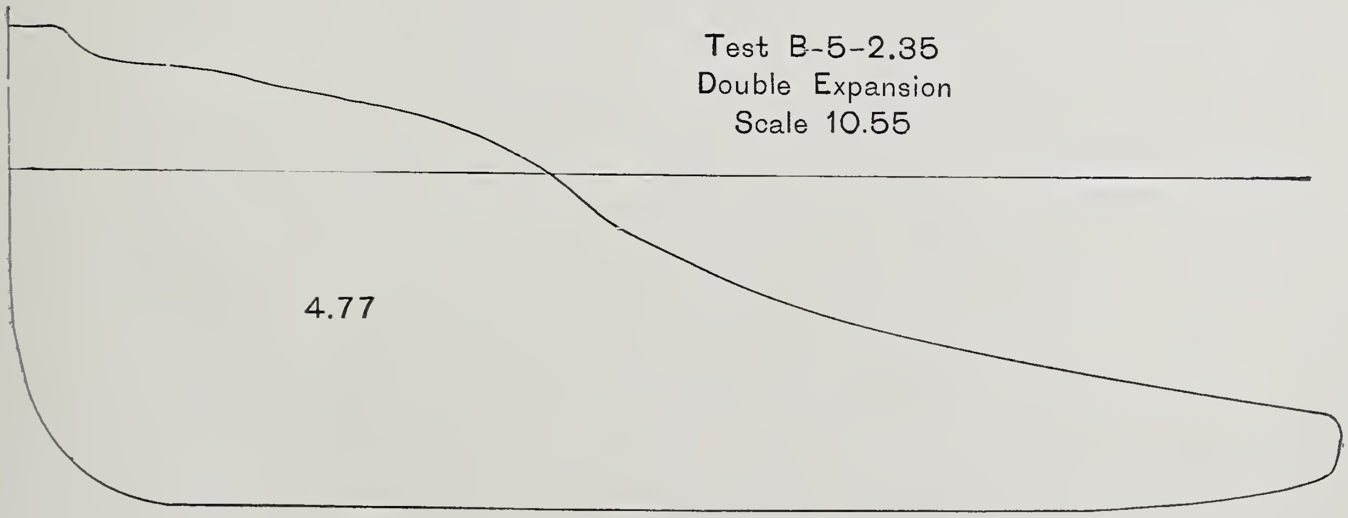


Fig. 178.

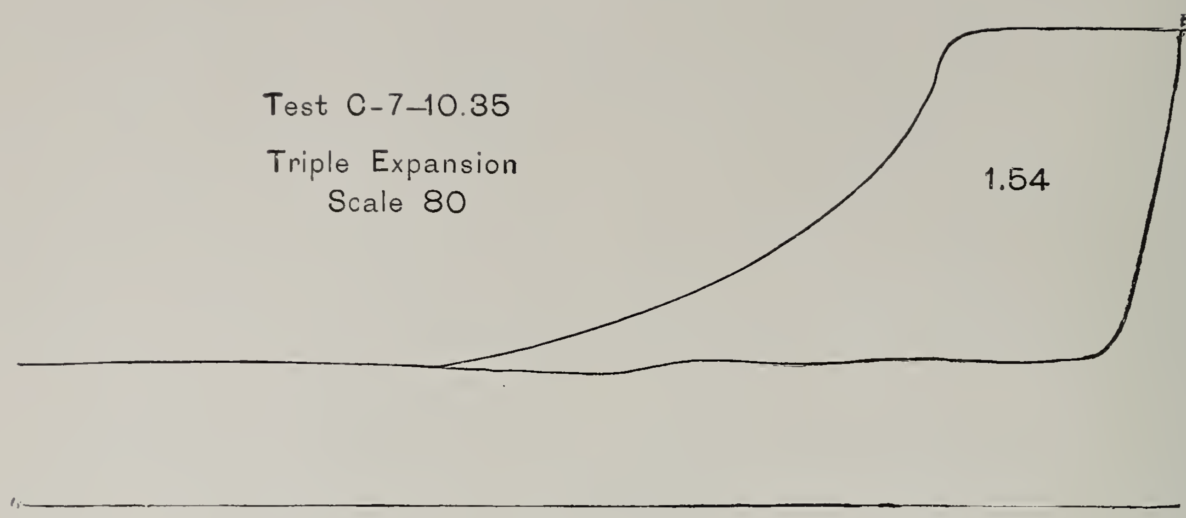


Fig. 179.

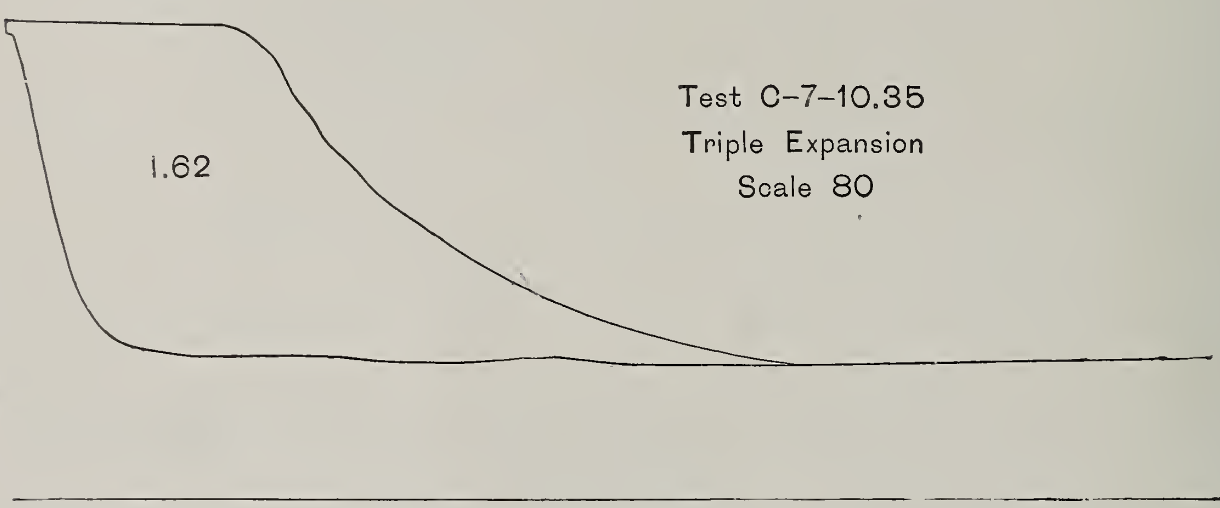


Fig. 180.

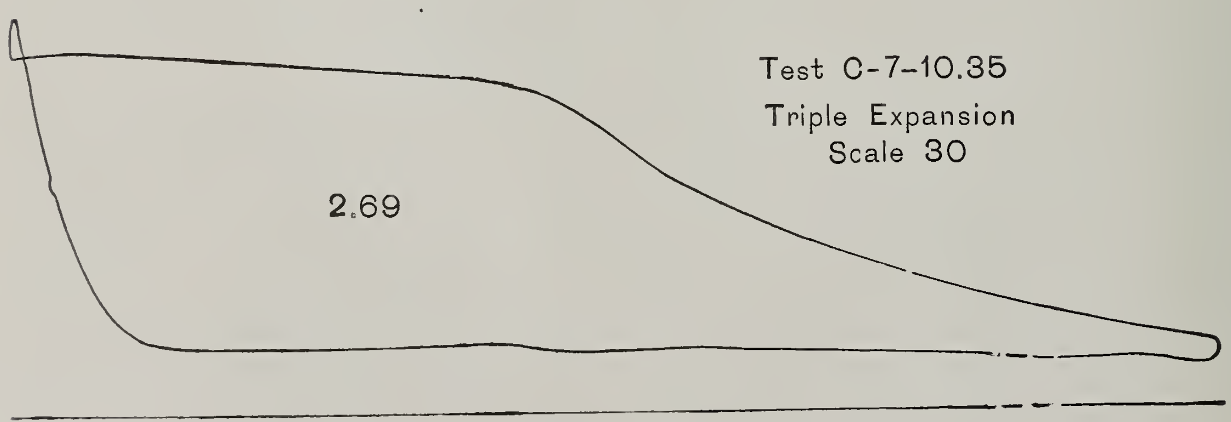


Fig. 181.

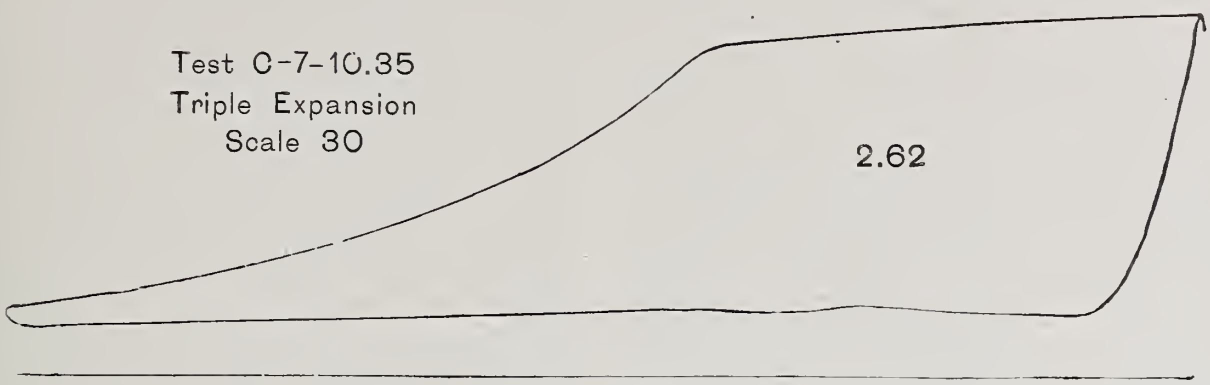


Fig. 182.

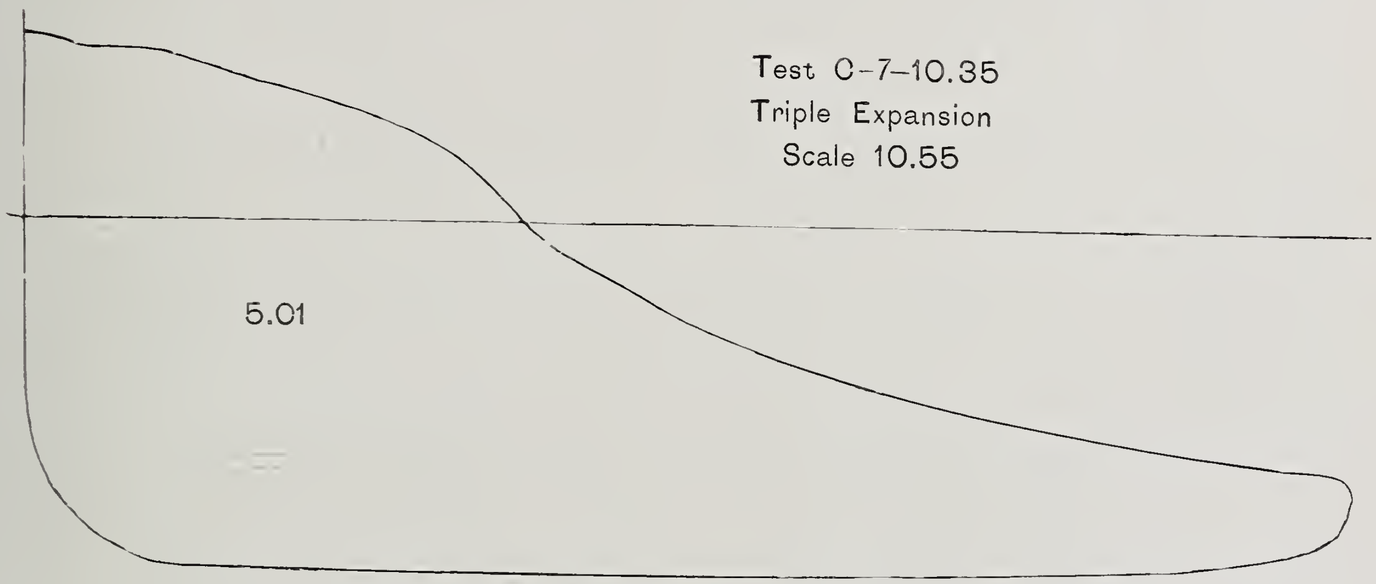


Fig. 183.

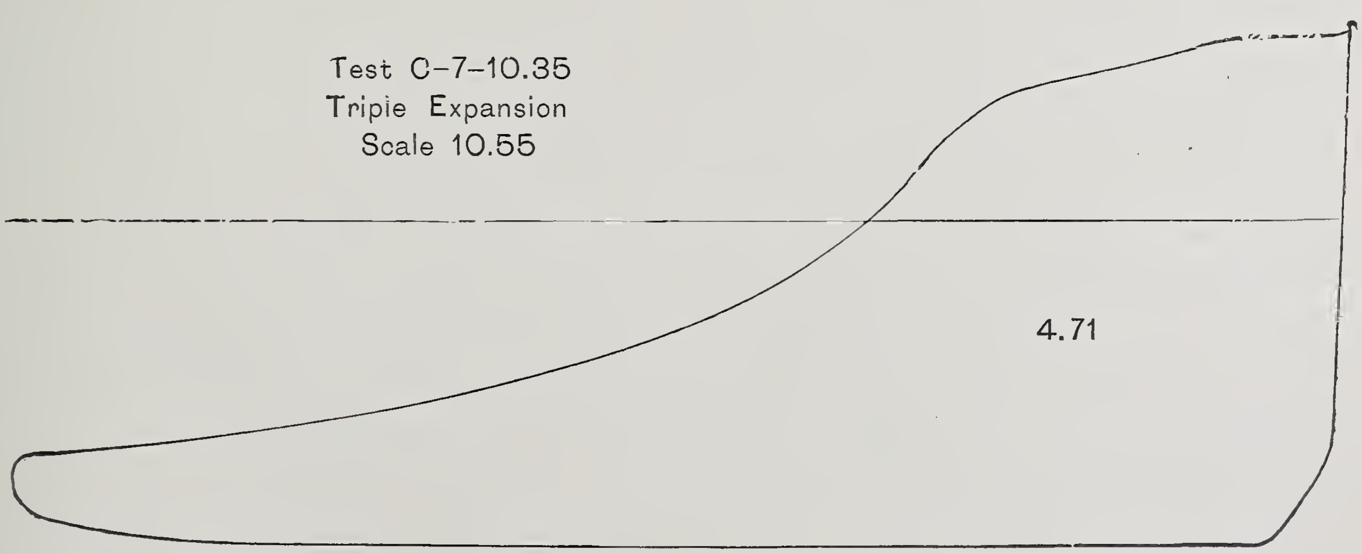


Fig. 184.

ter in the calorimeter was practically constant, showing a uniform degree of moisture in the steam amounting to 2.64 per cent.

On Wednesday, April 6, two five-hour formal trials of the engine, run as a two-cylinder compound, were held. During Thursday, a holiday, the change was made to a triple-compound, and on Friday two five-hour trials were again made. The sample diagrams appended (Figs. 175 to 184) show the valve-setting and degree of expansion. The results are seen in Table No. 2. They are practically identical, and would seem to support Mr. Rockwood's theory that the receiver may be so constructed as to take the place of the intermediate cylinder or cylinders of the multi-cylinder engine. As these tests were held so shortly before the spring meeting of the Society, the time allowed in which to prepare this paper was much too limited to admit of the exhaustive treatment which the importance of the subject demands. It is hoped that at the next meeting the results of further trials, together with their proper analyses, may be presented for further consideration. But the results of the tests, it is believed, show an economical performance surpassing the best records hitherto published in this country, and clearly indicate that more than two cylinders are unnecessary to secure the highest attainable economy in the use of steam.

TABLE II.

GENERAL RESULTS OF FOUR TESTS OF A TRIPLE-COMPOUND ENGINE, RUN BOTH AS A TRIPLE AND AS A DOUBLE COMPOUND.

Test.	Engine.	Duration, Hours.	R. P. M.	Average Steam-Pipe Pressure.	Average Indicated Horse-Power.	Water per I. H. P. per Hour.	Dry Steam per I. H. P. per Hour.	Weight of Water used in Jackets per Hour.
						Lbs.	Lbs.	Lbs.
A....	$\frac{12 \times 36}{24\frac{13}{32} \times 48}$	5 (7-12)	79.2	142.	187.11	13.41	13.06	330.3
B	$\frac{12 \times 36}{24\frac{13}{32} \times 48}$	5 (1-6)	79.3	142.	180.71	13.11	12.76	330.3
C.....	$\frac{\frac{12}{16} \times 36}{24\frac{13}{32} \times 48}$	5 (7-12)	79.0	142.	199.08	13.01	12.67	416.0
D.. ..	$\frac{\frac{12}{16} \times 36}{24\frac{13}{32} \times 48}$	5 (1-6)	79.0	143.	178.16	13.25	12.90	388.8

TYPICAL AMERICAN CRANES.—II.

By Henry Harrison Suplee, Member Am. Soc. M. E.

THE locomotive crane is in no sense an American crane, and, indeed, its introduction into this country from England is a matter of comparatively recent date, but the locomotive crane as built in America, for American duty, is a very different machine from its English prototype. In its functions it resembles the pillar crane, being a radial crane, either with fixed radius, or a radius variable by hand or by power ; but in addition to the functions of rotation and hoisting, the locomotive crane possesses the capacity of self-propulsion, and is not only a power crane, but is also self-contained, carrying with it its own boiler and engines.

Although of but recent introduction, the great utility of the locomotive crane is rendering it of constantly increasing popularity, and as its valuable features are more widely known, it is destined to become very generally used.

For contractors' work upon excavations, embankments, and masonry construction, and for service in steel and iron works and similar situations, this type is especially valuable. In some forms the engines are horizontal, the various functions of rotation, hoisting, and propulsion being effected by means of suitable clutches, and the control over the engines is accomplished by reversing link motion. In the English built cranes jaw clutches are generally used and propulsion effected by chain transmissions, but cranes of American design are fitted with friction clutches, and propelled by direct gearing.

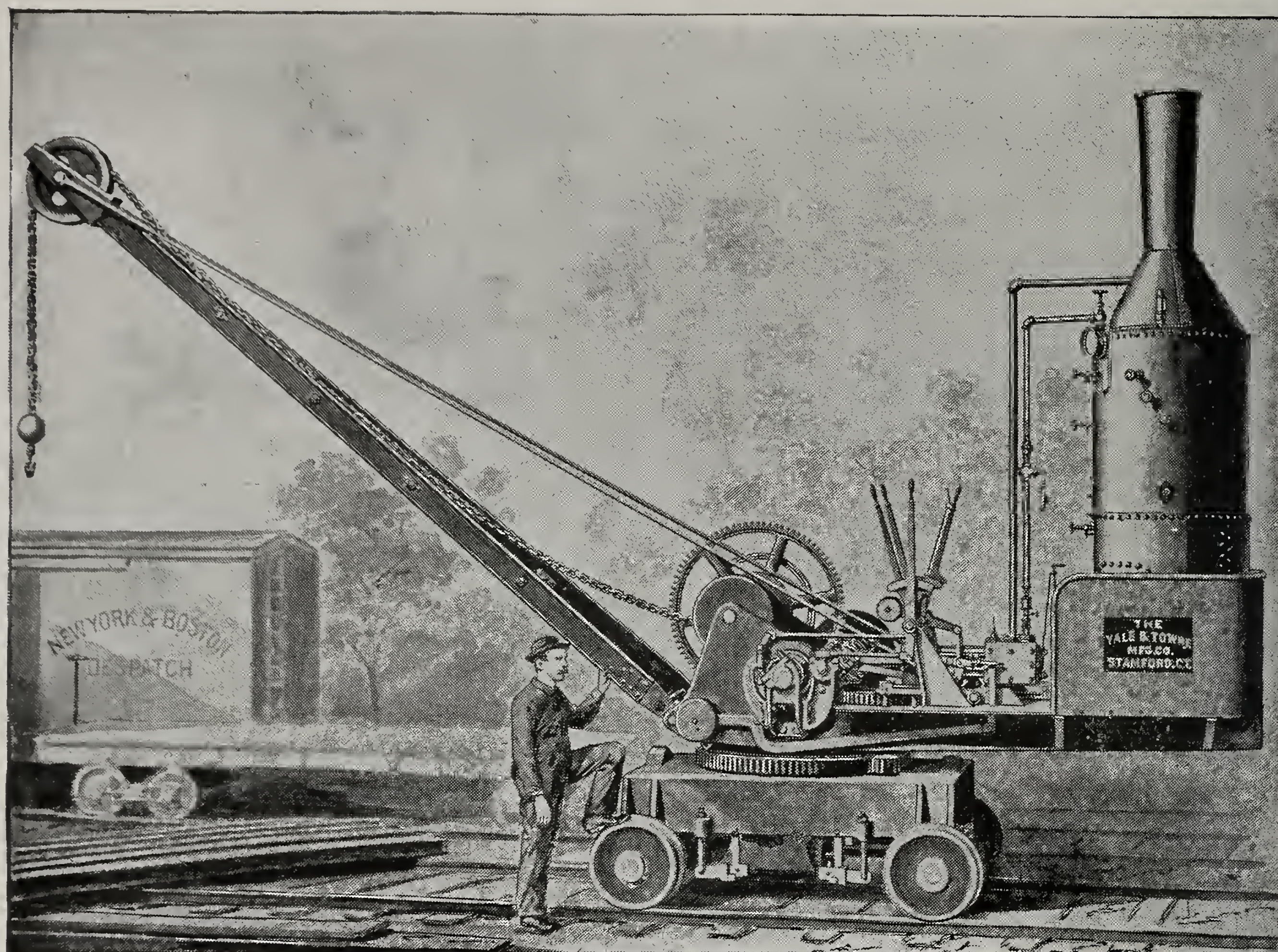
Cranes of heavy capacity are usually made with vertical engines, and the arrangement of the gearing and transmission is shown in the examples illustrated. The ease with which all the movements of these cranes may be controlled by a single operator renders them very efficient, since a touch of a lever is sufficient to govern any movement at will. An interesting and ingenious detail of some locomotive cranes is the Grafton slip ring, an English invention, by which safety against accidents, from too sudden application, or cessation of rotation, is secured. The large gear ring, upon which the upper portion of the crane rests, is not bolted fast to the truck frame, but rests upon a turned seat, the crane riding upon it by means of rollers. The friction between the ring and the truck frame opposes sufficient resistance to the rotative force necessary for the proper work of the crane, but should the motion be suddenly thrown on, or should the load suddenly be arrested, the ring will slip, and thus prevent serious shocks which might otherwise occur. The action of the ring is analogous to the slipping of the driving wheels of a locomotive engine when starting a heavy train, and affords a valuable protection against injury to the machine or to its load. Locomotive cranes are made either of wide or standard gage, the former, of course, giving greater base and stability.

Traveling cranes are of a totally different type from those which have been described, and, indeed, the two great types of cranes correspond to the two systems of mathematical notation, viz : polar and rectilinear co-ordinates.

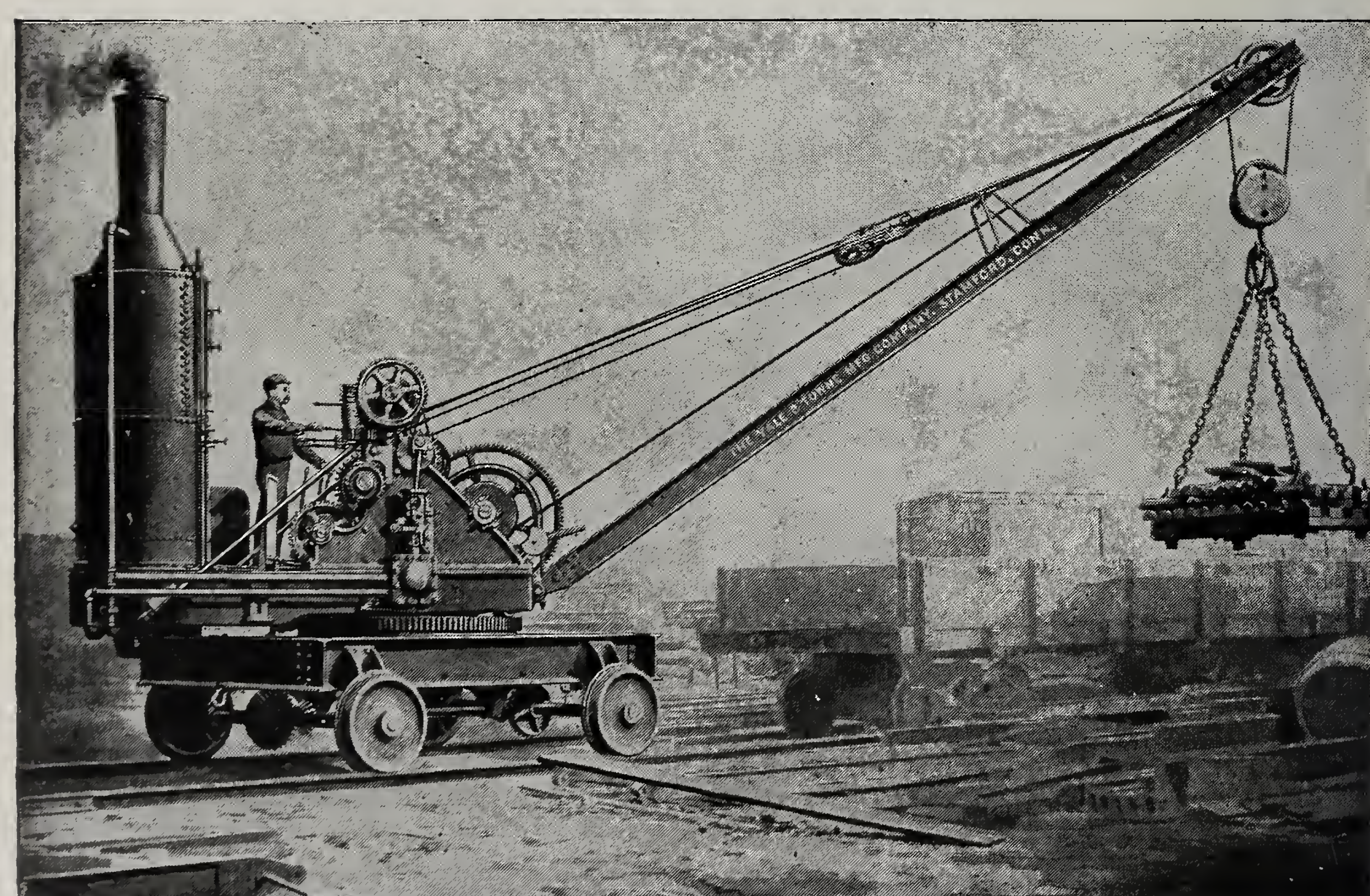
Jib, pillar, and locomotive cranes belong to the polar system, and cover an area within the circle of the radius, or in the case of the locomotive crane, within the raduis, at successive positions of the centre of rotation.

Traveling cranes, however, as the term is understood in this country, are of the rectilinear type, and cover a rectangular area very effectively. The idea of a traveling crane is frequently associated only with power traveling cranes, but very efficient and useful service is being rendered in many places by numerous forms of hand traveling cranes.

These cranes are most useful and serviceable, and involve but little care or skilled knowledge in their use. The traveling bridge is usually made of rolled beams, and travels upon rails



TWO-TON LOCOMOTIVE CRANE.

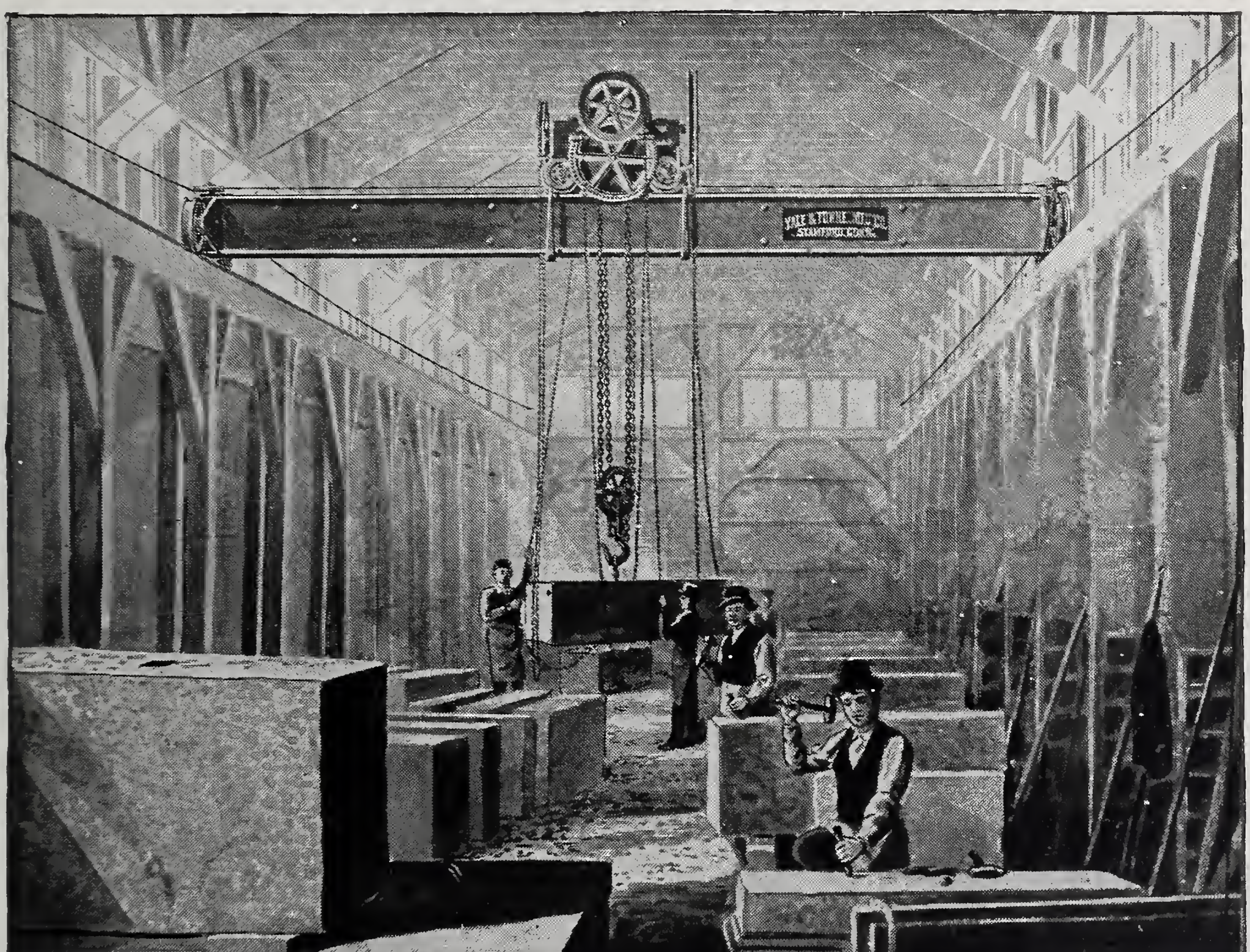


TEN-TON LOCOMOTIVE CRANE. VARIABLE RADIUS.

usually carried upon posts, which also form a part of the building. This in itself is an important feature, since the severe lateral strains caused by jib cranes are replaced by vertical pressure, which is more readily met and borne. The bridge is kept square with the rails, by some form of squaring device, either a cross shaft insuring equal propelling speed to the truck wheels at both ends of the bridge, or by squaring ropes extending from end to end of the building and crossing on the bridge. These ropes form a portion of the bridge propelling gear, and insure the uniform movement desired for both ends, the action being similar to the parallel motion used in modern drawing boards as a substitute for the old time T square.

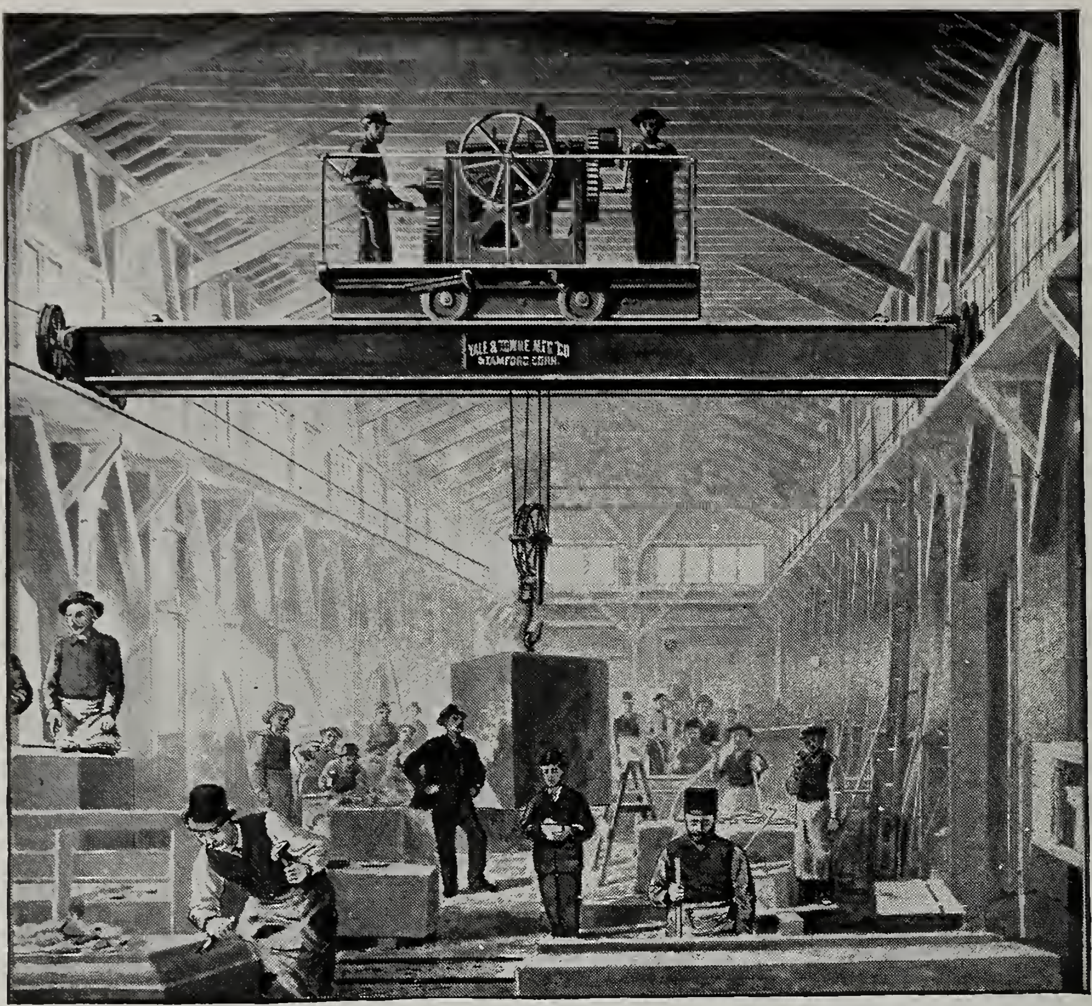
The cross movement on the bridge is effected by a trolley, moving upon rails on the bridge beams, and the hoisting chain depends from the trolley, so that the entire floor is covered. In some forms the motions are effected by hand chains depending from the trolley, and where the proximity of the operators to the load is not objectionable, this is a very convenient form. For handling hot metal, or material giving off gases or vapor, the operating mechanism may be attached to a pendant suspended from one end of the bridge, while in other forms a pendant platform is used, the operators turning cranks, and riding with the bridge.

In some cases an entire clear space below the bridge is desired, and the operators are then placed upon a platform surrounding the trolley and travel both with the trolley and the bridge. All the functions are then effected by hand cranks, and for service up to ten tons cranes of these forms are well adapted.

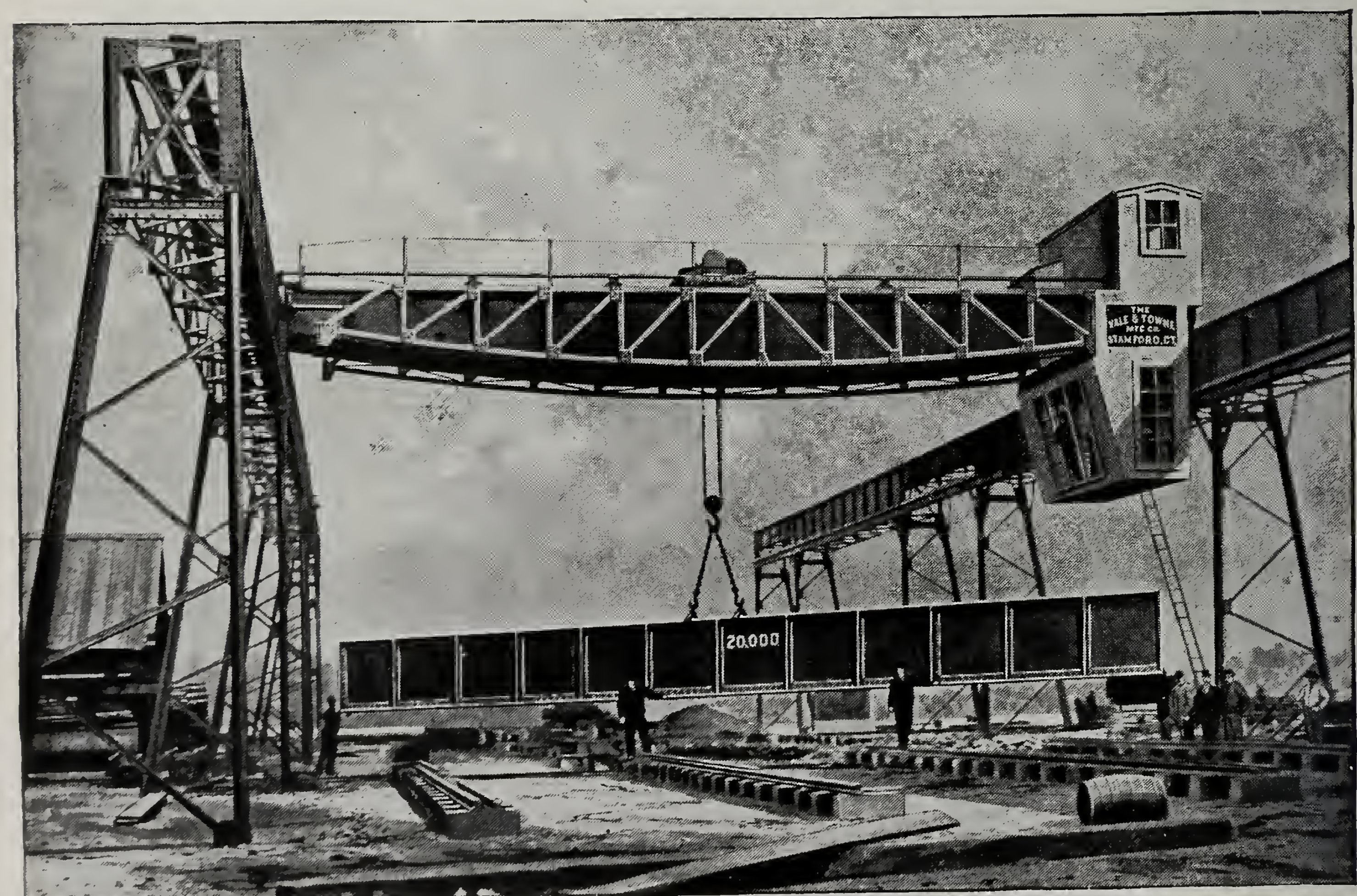


HAND TRAVELING CRANE. OVERHEAD TROLLEY CRAB.

The power traveling crane is undoubtedly the highest type of crane yet made, and, indeed, is fairly to be ranked among the most highly organized machines of any kind. All the functions are produced by power, and are under the immediate control of a single ope-



HAND TRAVELING CRANE WITH PLATFORM TROLLEY CRAB.

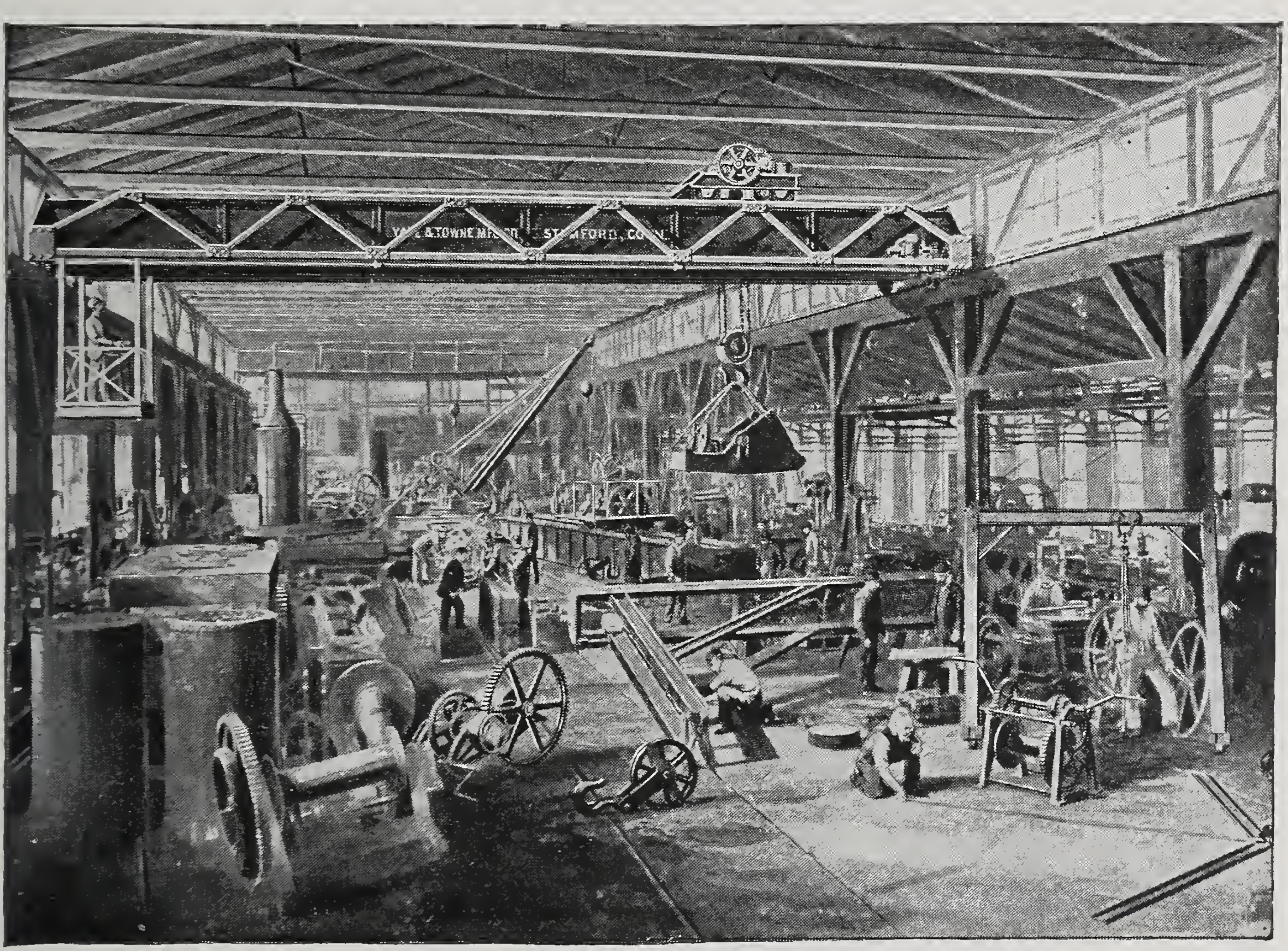


ELECTRIC-POWER TRAVELING CRANE. SINGLE MOTOR.

rator, and to witness one or several of these great and powerful machines traversing the length of a great machine shop or erecting floor, picking up, transporting, and placing the heaviest pieces, or the smaller articles, with a facility and accuracy almost human, is to realize the growth of modern facilities for handling materials in a manner not otherwise possible of appreciation.

Power traveling cranes have been made to be operated by rope transmission and by square shaft connection, mere contact, at once dispenses with flying rope or revolving shafting, and a consequent simplification of construction effected. When a single motor is used, as in the case of the out-door crane illustrated, a shaft is used upon the bridge to transmit motion to the trolley.

As in the case of steam-power cranes, however, the three motor type offers numerous advantages, and the use of independent motors for each function still further simplifies the mechanical construction. In the three-motor crane,



ELECTRIC POWER TRAVELING CRANE. THREE-MOTOR TYPE.

the terms referring to the method of getting the motive power from a stationary source to the moving bridge and trolley.

The applicability of electric power for this purpose is, however, meeting with wide-spread appreciation, and the latest, and, undoubtedly, a typical American crane, is the electric power traveling crane. The facility with which an electric current can be transferred from a stationary to a moving member, by one motor operates the bridge propelling gear, one effects trolley travel, and the third operates the hoisting drum, and all three motors obtain their current from the main line, and are under the instant control of a single operator. The use of proper switches and rheostats effectually prevents too sudden throwing in of the current to the motors, and permits gradual starting and insures full control.

In the power traveling cranes illus-

trated, the bridge beams are stiffened laterally by horizontal trusses, the trusses being supported by light vertical trusses, and the whole forming a light and effective substitute for the heavy box girders, frequently used in English traveling cranes.

While the types, which have thus been briefly shown, are not all American in their origin, they have all been so thoroughly acclimated as to be fully entitled to the title which has here been given them, and are undoubtedly destined to play an increasingly important part in the relief of mankind from purely laborious work.

NOTES ON A PROBLEM IN WATER-POWER.*

By John Richards, Editor "Industries."

THE present paper is a non-scientific one, and in other respects is not to be classed among the contributions such as are commonly presented before the A.S.M.E. Neither are its objects the same. The purpose is to present some thoughts upon a very important subject, with a view to calling out further and more able discussion. There being nothing exact or determinate to deal with, there will be neither figures nor quantities included, so that no severe mental strain need be apprehended in the following remarks.

The subject is water motors, or, as we commonly say, water-wheels, for utilizing the action of gravity on water, and an inquiry into the probable conditions, inferences, or deductions which have led up to and established modern practice as it now exists in this country.

Water-wheels, as we have to deal with them, may be classed as gravity wheels, including (1) overshot breast wheels and perhaps the Poncelet types; (2) pressure wheels, including what we call enclosed turbines and reaction wheels; (3) impulse wheels, driven by spouting water.

The classification thus assumed is, for short: gravity, pressure, and impulse wheels. These may be said to cover the various types in common use.

In modern practice the class called pressure turbine wheels constitute perhaps four-fifths of the whole. These can be divided into three general types, namely: The Fourneyron, or outward radial discharge; the Jonval, or downward discharge parallel to the axis of rotation; and the American, or inward flow wheels. These have come into general use all over the world, and have a literature of surprising completeness. They are by common consent regarded as the most efficient and, indeed, until recently, have been the only wheels which were considered in connection with an efficiency beyond 60 per cent.

The question to be presented and the main point in this communication is, What has produced this particular form of evolution in water-wheel practice? and why has pressure instead of impulse been the principle, or mode of operation, followed in all countries?

Before attempting any answer to this inquiry, it will be well to further examine or explain, in as simple a manner as possible, the nature of the class called pressure turbine wheels.

A column of water resting upon the vanes of a turbine wheel, which are free on their reverse side, and meet no resistance there, represents complete

*Paper read before the American Society of Mechanical Engineers.

efficiency less machine friction ; and the science of turbines, to so call it, is directed to removing the impeding water and its resistance on the reverse side of the vanes, that is, on the discharge side, after the function of pressure has ceased or has been utilized. It is common to divide the effect of the water, or its functions, in this class of wheels, into gravity, impulse, and reaction, but there is no need of such assumption or introducing the complex nature of these forces thus combined, because the whole is explainable as simple pressure, and all observed phenomona point to this as the "mode of action" in pressure turbines.

I am in this assumption no doubt transgressing upon what are called established data, but the issue is not important to the present subject, and it will be sufficient to call the active force one of pressure alone, and the resistance or loss a result of an imperfect riddance of the water on the reverse or discharge side of the vanes after it has performed its work by pressure, impulse, or otherwise.

Following this method of operating to its constructive features, it involves closed vessels, or conduits, not only to the water-wheels, as in other cases, but around them. They must be enveloped in the fluid that drives them, and contained in cases strong enough to sustain not only the static head, but also the effect of water concussion, and in most cases afford support for the wheels themselves and their shafts.

The bearings of the wheels have to sustain the weight of the running parts, also in many cases a pressure of the head, equal to the area of the issues multiplied into the head. The wheels are submerged, placed at the bottom of the head or near it, inaccessible to observation, and also for repairs, calling for unusual and expensive provision in the way of bearings and other constructive features, including extra strength of all parts. The hydrodynamic conditions both of entrance and discharge call for complicated forms that cannot with safety be built up, and pressure turbine wheels thus become large and expensive castings, the value of which depends upon the integrity of every part. If a vane be broken or imperfect, the whole wheel is lost. The diameter being limited because of first cost, a limit of rotative speed is reached at heads of fifty feet or so, and even at that head the bearings have to run under undesirable conditions ; in other words, this type of wheels does not permit control of rotative speed, that being limited by both first cost and operating conditions.

Turning now to the other type of wheels, but little known in this country except on the Pacific coast, the impulse class, and assuming that the force of spouting water is equal to its gravity less an inconsiderable friction in orifices, the question arises, Why has not the evolution of water-wheels followed on this line instead of pressure for all except low heads?

This is a very important question, one that may well engage the attention of this Society, and one that calls for explanation such as will be by no means easy or apparent. It is true that with that class of impulse wheels called "undershot," and some other cruder forms operating by the impulse of spouting water, the efficiency attained has been so low as to lead to the conclusion that the losses were inherent in the method, or mode of operation, and this opinion has, it seems, become general without anyone very closely inquiring into the matter.

That the efficiency of tangential wheels driven by impulse is as high as can be attained by pressure turbines has been proved by numerous experiments here, also by some recent tests at Holyoke, Mass., and is beyond controversy. It has long been settled on this coast, and as a problem no longer exists. No one here would expect under a head of fifty feet or more to attain with any known type of pressure water-wheels a higher efficiency than is given out by tangential impulse wheels ; but this state of opinion and practice is confined to narrow limits now, and is the more to be wondered at when we consider the rapidity and completeness of investigation in other branches of dynamic engineering at the present day, especially when the economic and constructive conditions so much in favor of the impulse type of water-wheels are taken

into account. These we will now consider in a brief way.

There is a wide difference between a water-wheel driven by impulse and one operating on the pressure system. The first cost of the former, for a given power, is one-half as much, and its maintenance is still less, in proportion.

Figuratively speaking, when a wheel is changed from the pressure to the impulse system it is taken out of its case, mounted in the open air, in plain sight. All the various inlet fittings are dispensed with and are replaced by a plain nozzle and stop-valve. Its diameter is made to produce the required rotative speed, whatever that may be. The shaft and its bearings are divested of all strains except those of gravity, and the stress of propulsion when the water is applied at one side only. Most important of all, there are no running metallic joints to maintain against the escape of water, no friction and no leaks; there are, indeed, no running joints or bearings whatever, except the journals of the wheel-shaft.

The effect of grit and sand is eliminated, both as to vanes and bearings, and there are no working conditions that involve risk or call for skill. If a vane is broken, another one is applied in a few minutes' time. If a large or small wheel is wanted, the change is inexpensive and does not disturb the foundations or connections.

Capacity is at complete control; the wheels can be of 10, 100, or 1000 H.P., without involving expensive special patterns. The speed of rotation is not confined to commercial dimensions because of patterns or other causes. It is merely a matter of choice with the purchaser or maker.

Now granting the efficiency of impulse wheels, which, as before remarked, can hardly be called in question for all heads exceeding fifty or even thirty feet, and conceding the constructive and operating advantages just pointed out, the question at first named arises, Why has the evolution of water-wheels during fifty years passed been confined to the pressure class? also, why has it been proposed at Niagara Falls to employ pressure turbine wheels under a head of 100 feet or more, when the conditions point to the better adaptation of open, or impulse wheels?

It is not necessary in such an inquiry to discuss the problem of horizontal and vertical axis, or other local conditions, in the case of the Niagara plant, or in any other case, further than to say that the pressure class of wheels offer no advantages, not balanced by equal or greater disadvantages, as will no doubt appear if there should be discussion of this subject before the Society.

Besides the object of this communication first named, there is the further one of calling the attention of the members present to the impulse or open water-wheels so extensively employed on this coast, and to suggest, that, if possible, they manage to see such wheels in operation under various heads, especially under high heads. In observing a machine of any kind in motion, there are impressions gained which cannot be conveyed by description, but I warn everyone against inference from this remark, that the tangential water motor wheels on this coast are not scientifically understood and treated. The problems involved may not be so many or so intricate as in the case of pressure turbine wheels, and this is fortunate, because the literature of the latter is one of much perplexity to any but skilled mathematicians, and for that reason has not been of so much use as it ought to have been in developing the wheels.

In this country, and it is a most commendable thing to mention, the pressure turbine by an inward flow, or an inward draught, has been greatly simplified in construction, cheapened in first cost, and at the same time better adapted to impure water, without losing anything in efficiency. I believe the inward flow turbines made by the Risdon Company at Mount Holly, N. J., have, in public tests on more than one occasion, shown an efficiency as high, or even higher, than the more finely fitted Fourneyron and Jonval types.

The record of American engineers in this branch is one of which they may well be proud; and now that impulse wheels of the Girard type have made much progress abroad, and have here in California been modified much as the Fourneyron and Jonval wheels have

been in the Eastern States, it is quite time more attention was bestowed upon them in other parts of the country. The analogy in the two cases is marked. By an inward flow American makers reduced the running parts, or the wheel proper, of pressure turbines to a small diameter, increasing its speed accordingly. This lessened the weight and cost of the wheels in the proportion of their diameters, and at the same time dispensed with the accurate fitting involved in the outward and downward flow turbines ; and this, as before said, has been done without sacrificing efficiency.

The tangential type of open wheels has been similarly dealt with here in California. The running-water joints have been wholly dispensed with. The construction has been cheapened one-half. The round jet has been applied in the most simple manner, with an increased dynamic effect, and the efficiency attained is believed to be more than is reached by the finest examples of Girard wheels in Europe.

Conceding these statements and facts brings us back again to the the query forming the subject of this communication, namely : Why has the evolution of water-wheels followed on the line of *pressure* instead of *impulse ?*

THE VALUE OF A WATER-POWER.*

By Charles T. Main, Member Am. Soc. M.E.

IN estimating the value of a water-power, especially where such value is used as testimony for a plaintiff whose water-power has been diminished or confiscated, it is a common custom for the person making such estimate to say that the value is represented by a sum of money which, when put at interest, would maintain a steam-plant of the same power in the same place.

For example, when a power of 100 H.P. has been taken by right of eminent domain, or by right given by an act of legislature, or by any other legitimate means, in estimating the value of such a power and its consequent loss to the owner, it is reasoned that taking into consideration the cost of fuel at that particular place, and other expenses of running, that a 100 H.P. steam-plant would cost say $50 per year per horse-power to run. $50 × 100 = $5000 per year for running the steam-plant. This, capitalized at 5 per cent. = $100,000, which is said to represent the value of the water-power.

At first glance this reasoning may appear to be sound, but upon examination it will be seen that it has no foundation, and probably there is no set of conditions under which it would absolutely hold good.

A water-power may be of more value for one kind of business than other, and its value is very largely determined by its location. But passing these by for the present, the value of a water-power depends upon :

1. The quantity of water, the fall, and the uniformity of flow during the year and for a succession of years. This is an axiom, and we should be obliged to go no further than this to dispose of the method of estimating values as stated at the outset.

(*a*) The effect of the fall is to increase or decrease the cost of construction per horse-power. If the fall is low the cost per horse-power of plant will be very much more than that for a high head. The value of that power of low head cannot be as great as that for the high head, other things being equal, for the first cost of plant and the fixed expenses, such as interest, depreciation, repairs, taxation, and insurance, will be greater for the lower head per horse-power ; so also will be the running expenses ; and to get the same return for the money expended, as more money is required in the construction of the plant with a low head, less value can be placed on the power itself.

(*b*) The effect of variable flow upon the value is more difficult to estimate, and to determine at what point of variability the power becomes of no value.

I am firmly convinced that to-day there are a great many concerns located upon streams which are so variable as to require an auxiliary steam-plant of a size equal to the water-power plant, or nearly so, to which in the past such water-power may have been a saving, but which now, if they could begin anew, could produce their power more cheaply from a single steam-plant than from the double plant.

It is true that fuel is saved, if steam is not required for other purposes than power, during such times as the engine is not run, but it is also true that as the engine is only to run for a portion of the time, it is probably deemed advisable to purchase a low cost steam-plant in order to reduce the fixed expenses, which means a larger consumption per hour than there would be with a better plant. At times also the engine will be underloaded, which is not conducive to economy. To the running expense must be added the cost of maintenance of a double plant, so that the cost is almost sure to be more than that of a single new efficient plant.

If the stream is variable and the water-power plant is the only source of power, which must stop for a portion of the time, it would be of very little value under

* From a paper read before the American Society of Mechanical Engineers.

such conditions except for a very limited range of business. No business, employing any amount of labor, carried on in such a way, could compete successfully with concerns which have a continuous run.

2. Other things being equal, the value of a water-power depends very largely upon its location.

On the basis of figuring indicated in the beginning the value of the water-power varied directly as the cost of fuel, therefore the farther away from a railroad the power is located, and the more it costs to haul coal to it, the more valuable would be the power. If there is raw material to be brought to the mill and finished product to be taken away, it is a self-evident fact that the nearer the railroad or seaport the mill can be located the more valuable the power which drives it. This reasoning can be carried to *reductio ad absurdum* by saying that a water-power is more valuable in the wilds of Maine, where there is no railroad and consequently where fuel is expensive, than in Lawrence, Lowell, or Manchester.

3. The value depends largely upon the fact whether or not the social conditions are or can be made such as to cause good operatives to locate and remain in the place; upon the sanitary conditions; and sometimes even, in the case of a developed power, upon the management of municipal or town government. All of which cannot be estimated in dollars and cents, but which determine to a certain extent the profits or losses.

4. There is in almost every business need for steam for other purposes than power, if for no other purpose, in colder climates, than for warming the buildings in cold weather. This steam can usually be used after being exhausted from an engine, requiring the consumption of little or no more fuel than is required to produce steam for the engine alone.

The plant required for producing the steam is a necessity when water is used for power, and should be included in the cost of power-plant, and the expense of running included in the cost of producing power. This item may be so large as to make a positive loss by running the boiler-plant for steam for heating and using water for power, over and above the cost of producing the power by a steam-plant and using the exhaust steam for heating purposes. This item then in itself is enough to overthrow the old method of estimating the value of a water-power in such a broad and general way.

I think it has thus far been shown conclusively that the old process of reasoning is wrong. It is always easier to criticise and to say that a thing is wrong than to say how to make it right, and it is much easier to show why the old method is wrong than to lay down a rule which shall cover the ground in a fairly corrected manner.

In order to show a method of estimating the value of a water-power it is necessary to consider the power first as undeveloped, and then, if it be developed, in its developed state.

By an undeveloped power is meant a natural fall or rapids, which, by the building of a dam or canal, or both, and by putting in water-wheels, may be made to furnish power, but which is in its natural condition, no labor having been expended upon it.

There are but few kinds of business which demand a particular and restricted location. For this reason it is obvious that in nearly every kind of business a location can be selected which will furnish the best returns for the money invested. With an undeveloped power there need be no feeling that a certain amount having been expended it is a total loss to locate elsewhere. There is nothing to bind a foreign concern to this particular undeveloped power. It has the range of at least a large section of the country from which to make a choice of location, and in case it is necessary to locate on a stream and advantageous to use water-power there will still remain a choice of location.

There are exceptions to this, in cases where the power can be used where the raw material abounds, and the finished product finds a market in the immediate vicinity.

The essential points which must be considered, as to whether an undeveloped power can be developed and used to a greater profit than any particular business or general run of business could

be conducted elsewhere with a different source of power, are as follows :

a. Quantity of water during a dry year.

b. Uniformity of flow during the year, considering the storage capacity, natural and artificial.

c. Head of fall.

d. Conditions which fix the expense of building dam and canal, and flowage of land.

e. Conditions which affect the cost of foundations for buildings.

f. Geological conditions which determine the permanency of the falls.

g. Freight charges for fuel, supplies, raw materials, and finished product.

h. How much low-pressure steam can be used for heating purposes, and whether exhaust steam can be used for those purposes.

i. Is water needed for other purposes than power, and in what quantities ?

j. The social and sanitary conditions which make it possible to procure and keep good help.

k. The greater uniformity of speed with steam than with water-power.

All the above items except the last two can be estimated approximately in money value.

The power which has the most value is one which has a flow during a dry year which is nearly constant, or which can be made so by storage basins, and which requires no augmentation from other sources. It seems to me to be fair, in determining the value of such a power, to say that if the business which can be conducted there can be conducted elsewhere, where fuel is cheaper, the cost of that water-power can be compared with the cost of steam-power at such places which are suitable for the transaction of such business.

For illustration, let us consider the constant portion of the power at Lawrence as undeveloped. There is an amount of power which can be depended upon nearly always of about 10,000 H.P.

There is no question but what the business which is located along the Merrimac in Lawrence, which is the very business for which the development was made, could be equally well carried on in some other location where fuel and transportation are cheaper than in Lawrence. Let us consider it located where coal can be obtained at $3 per ton.

The amount of heat required per horse-power would vary with different kinds of business, but taking it for an average plain cotton-mill, there is an amount of steam required for heating and slashing which is equivalent to about 25 per cent. of steam exhausted from the high-pressure cylinder of a compound engine of the power required to run that mill, the steam to be taken from the receiver.

Supposing this power produced by steam with plants averaging 500 H.P. each.

The coal consumption per horse-power per hour for a compound engine is taken at 1¾ pounds per hour, when no steam is taken from the receiver for heating purposes. The gross consumption when 25 per cent. is taken from the receiver is about 2.06 pounds.

75 per cent. of the steam is used as in a compound engine at 1.75 lbs. =	1.31 lbs.
25 per cent. of the steam is used as in a high-pressure engine at 3.00 lbs. =	.75 lbs.
	2.06 "

CROSS CONSUMPTION.

The running expenses per horse-power per year are as follows :

2.06 lbs. coal per hour = 21.115 pounds for 10¼ hours or one day = 6503.42 pounds for 308 days, which at $3 per long ton =	$8.71
Attendance of boilers, one man at $2, and one man at 1.25 =....................	2.00
Attendance of engine, one man at $3.50	2.16
Oil, waste, and supplies....................	.80
The cost of such a steam-plant in New England and vicinity of 500 H.P. is about $65 per horse-power. Taking the fixed expense as 4 per cent. on engine, 5 per cent. on boilers, and 2 per cent on other portions, repairs at 2 per cent., interest at 5 per cent., taxes at 1½ per cent. on ¾ cost, and insurance at ½ per cent. on exposed portion, the total average per cent. is about 12½ per cent., or $65 × .12½ =	8.13
Gross cost of power and low-pressure steam per horse-power.	$21.80

At Lawrence the cost of dam was $250,000 ; the cost of North canal about $250,000, and of South canal about $150,000, or a total sum of $650-000, or about $65 per horse-power. The

cost per horse-power of wheel-plant from canal to river is about $45 per horse-power of plant, or about $65 per horse-power used, the additional $20 being caused by making the plant large enough to compensate for nearly all the fluctuation of power due to rise and fall of river. The total cost per horse-power of developed plant is then about $130 per horse-power.

The dam at Lawrence has a record which probably is unequaled elsewhere. It has shown no signs of weakness or leakage, and has required no work to be done on it since its completion. This cannot be said in most cases. The canals, of course, do not require renewals, but do require repairs. The gates, locks, etc., require renewals. Several portions of the plant from canal to river require renewals at intervals. I have placed the depreciation on the whole plant at 2 per cent., which perhaps is high for Lawrence, but none too high for the average plant; repairs at 1 per cent.; interest at 5 per cent.; taxes and insurance at 1 per cent, or a total of 9 per cent.

Fixed expenses per horse-power $130 $\times .09 =$	$11.70
Running expenses per horse-power (estimated)	2.00
	$13.70

The amount of steam required for heating purposes we have said to be about 25 per cent. of the total amount used, but in winter months the consumption is at least one and one-half times the average consumption, or 37½ per cent. It is therefore necessary to have a boiler-plant of about 37½ per cent., the size of the ones previously considered with the steam-plant, costing about $20 $\times .0375 =$ $7.50 per horse-power of power used if the source of power is water.

The expense of running this boiler-plant is as follows:

Fixed expenses at 12½ per cent., $7.50 $\times .125 =$	$0.94
$2.06 \times .25 = .515$ pounds coal per hour average consumption per horse-power. $.515 \times 10.25 \times 308 = 1626$ pounds per year at $4.50 per ton $=$	3.26
One man at $2 per day $=$	1.23
	$5.43

A plant of minimum size, used for heating buildings alone, would be about 20 per cent. of the size required for power. $20 $\times .20 =$ $4 per horse-power of power.

The fixed expenses would be $4 $\times .125 =$	$0.50
Coal, 0.5 ton per horse-power per year at $4.50 per ton	2.25
Attendance, one man at $2 per day for 150 days	.60
	$3.35

The effect of item *g* can be estimated approximately by knowing the difference in charges for freight between our proposed location on the river and elsewhere equally suitable in other respects.

In an ordinary plain cotton-mill, of average numbers of about 30, the weight for raw material brought to the mill would be about 40 tons per 1000 spindles. The outgoing freight would be about 30 tons of finished product and 5 tons of waste. Calling all other supplies, etc., 5 tons, we have a total weight moved of about 80 tons. Taking the power required as 20 H.P. per 1000 spindles, the amount of freight per horse-power would equal $80 \div 20 = 4$ tons per year. If a saving of 50 cents per ton can be made by locating nearer the base of supplies and markets, the saving per horse-power would be $2 per year. This amount of saving should either be deducted from the cost of steam-power or added to the cost of water-power in getting their comparative value.

There is another portion of item *g* which cannot be expressed in money, and that is the advantage of nearness to markets for sale of goods.

Item *i*. If water is required in large quantities for other purposes than power, for washing, etc., an estimate should be made of the cost of providing this away from the stream, and this amount deducted from the cost of water-power or added to the cost of steam-power. Let us assume that in the case under consideration the cost would be $2 per horse-power per year.

Considering all the other items of equal value in each case, we should have the total costs as follows:

Steam-power as given	$21.80
Water-power, $13.70 + 5.43 + 2.00 — 2.00 = ...	19.13
Difference in favor of water-power ..	$2.67

$2.67 + 10,000 = $26,700 per year saving on 10,000 H.P.

Now it is fair to say that the value of this constant power is a sum of money which when put at interest will produce the saving; or if 6 per cent. is a fair interest to receive on money thus invested, the value would be \$26,700 ÷ .06 = \$445,000.

I do not want it understood that this is my estimate of the value of that portion of the water-power at Lawrence which is constant, for certain premises have been assumed for illustration simply without a knowledge of all the truth.

If there are no other considerations than power, it will be profitable to develop a power so long as the conditions fixing the cost of construction and running expense do not bring the fixed and running expenses so high that the total cost per horse-power for water-power will be equal to that of steam-power. When that point is exceeded it would be folly to develp the water-power.

The cost per horse-power for the dam would not increase in the inverse ratio as the head, but the cost of canal and that portion of plant from canal to river would increase very nearly in that ratio.

So that if at 28 feet head the cost of plant is \$130 per horse-power, at 10 feet head the cost would be nearly 2.8 times as much, or say \$350. The fixed expense in this would be \$350 × .09 = \$31.50, and running expense say \$5, making a total of \$36.50 per horse-power per year, which is far beyond our cost given for steam-power.

The other conditions affecting the cost and running expense would work for or against the development.

In almost every concern there is use for low-pressure steam to a greater or less extent. If exhaust steam can be used for these purposes the net cost of steam-power is reduced, the cost dropping to a very small sum if all of the exhaust could be used.

In a plain cotton-mill about 25 per cent. of the exhaust from the high-pressure cylinder of a compound engine can be used on an average throughout the year. Establishments with dye-houses, or where drying is done, can use more, and it is safe to say that if it should not be known what particular business is to be carried on at a location under consideration, an average of 25 per cent. of exhaust steam could be used.

For powers which are to be used in larger or smaller amounts than 500 H. P. the relative costs would change; but a similar method of arriving at such values could be used.

THE ELECTRIC RAILWAY AS APPLIED TO STEAM ROADS.*

By B. J. Dashiell, Jr.

THE intention of the writer is to give some information which will throw light upon the question of high-speed train resistance, deduced from tabulated experiments at such speeds.

The first experiments of note at extremely high railroad speed were made by the Electro-Automatic Transit Company, of Baltimore city, in the year 1889, at Laurel, Md., on their cricular road, with a 2½-ton car. Some of these experiments were publicly reported by Mr. O. T. Crosby, in his paper entitled "Report of High-speed Electric Railway Work."† Mr. David G. Weems, the originator, contemplated having an automatic mail and express service from one city to another, controlling the cars from central stations located on the line of the road, and which was to be a very complete "block system" in its way. In the early spring of 1888 my services were required by this company, and designs and experimental circular tracks were made and built under my direct supervision. I may here state, for the benefit of some not knowing the circumstances, that the line of road was built for a *limited sum* of money, and that in some of the experiments, owing to some "fixed ideas," the motors were designed for too high a speed. Both of these obstacles gave us quite a little trouble on the start.

The power-house consisted of a 30-foot x 40-foot x 12-foot wood building, costing about $600 to build. It was divided into three rooms,—boiler-room, engine and dynamo-room, and office. The plant consisted of 125 H.P. in two (2) vertical boilers 100 H.P. Ball high-speed, automatic cut-off engine, running at 300 revolutions per minute, and connected direct by a double belt with a No. 20 Edison generator of 50,000 watts capacity, which supplied the traveling car with energy.

The motor car (Figs. 72, 73) had a wheel base of 9 feet; four driving wheels, 28 inches diameter, of cast-steel plate web, 1¼-inch flange, and 2¼-inch tread; gage of track, 28 inches; two (2) axles of 3-inch machinery steel, each carrying a gearless motor of special design, being a two (2) pole machine of the "U" type, and suggested very much in appearance the Sprague street-railway motor. During the whole course of experiments no trouble was experienced by the slightest electrical accident. I can well say that this is a record which the street-railway people can envy, and will place confidence in future high-speed work. I am informed that these motors and cars will be placed on exhibition at the World's Fair in Chicago next spring. The extreme length of the car was 21 feet 6 inches, having each end pyramidal; the body width of the car was 24 inches and it was 30 inches deep, thus exposing a sectional area of about 5 square feet to the atmosphere. On the top of the car at each end were placed guide shoes or wheels, which were designed to act as an additional safeguard in passing up against the upper T-rail or conductor, and thereby helping to keep the car on the track. Ends of different shape were placed at various times on the cars, as well as flat movable ends, thus getting readings of the extreme air pressure upon the car in its direction of movement. The electric current was taken from the overhead rail by means of a copper strip brush, and then conveyed to the motors, which were connected in multiple at one time and in series at another. The armature was wound with No. 12 B. W. G. copper wire, with 100 sections of two turns per section. Each field-spool coil, of which there were two to each motor,

* Paper read before American Society of Mechanical Engineer.

† *Trans. Amer. Inst. Elect. Engrs.*, February 24, 1891.

was wound with 120 turns of No. 4 B. W. G. copper wire ; the armature section consisted of soft iron wire of about 21 square inches section, and the pole pieces about 40 square inches.

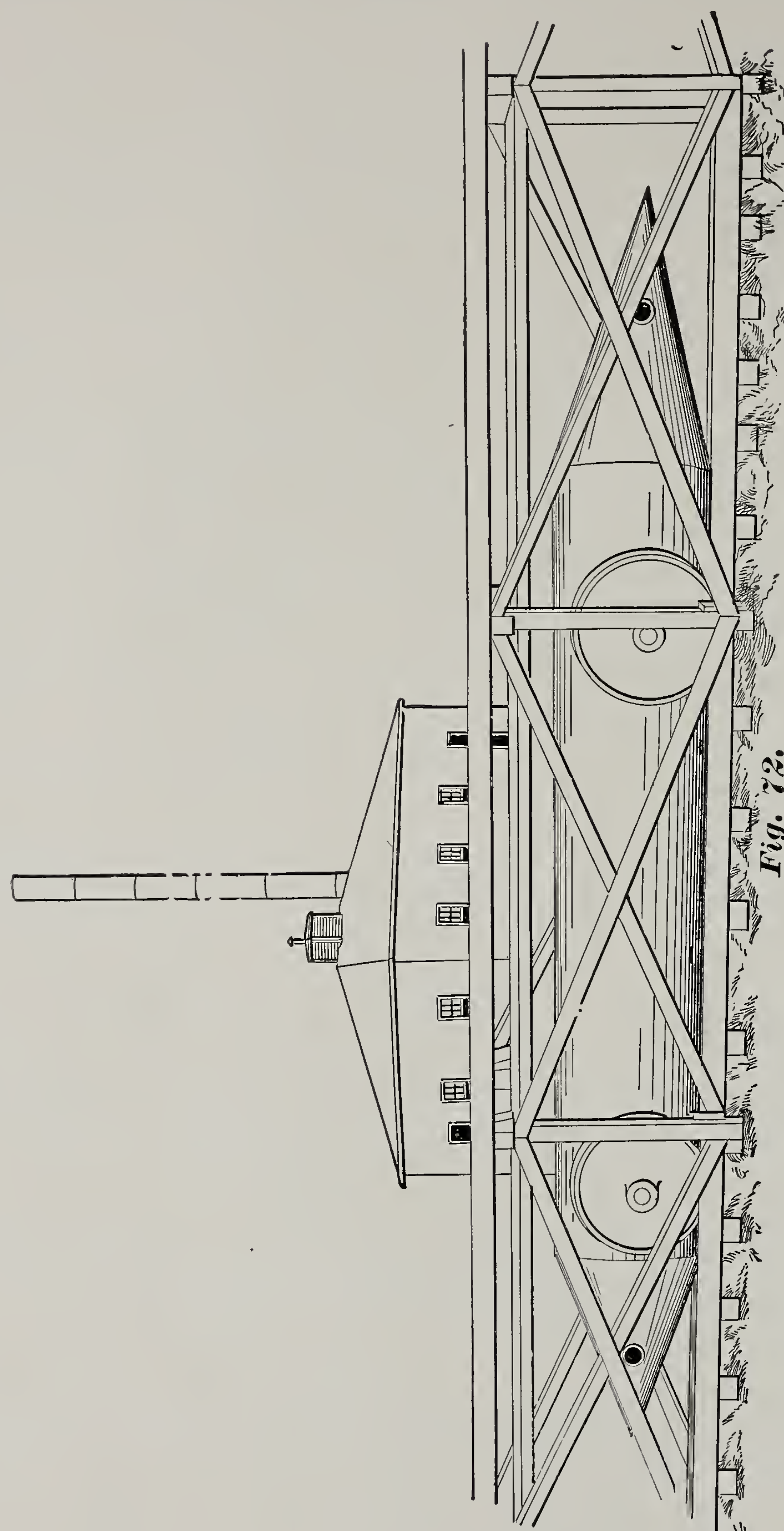


Fig. 72.

The track was built in a true circle of nearly two miles in circumference, having a gage of 28 inches, the upper rail being 36 inches from the top of track, and was placed in the center ; along each lower rail on the outside was placed a yellow-pine guide stringer or guard rail. All rails were electrically bonded. The ohmic resistance of one-half the circular track was about 0.25 ohms.

The super-elevation of external rail

varied from 2¾ inches to 3½ inches, according to the grade and direction in which the car ran. During these experiments we experienced only three derailments, two of which occurred at 45 and 80 miles respectively, and were due to a portion of the road being poorly ballasted. These two derailments were toward the center of the circle, the car leaving the rail only, and running along the guard rail. In the third derailment, which was due to not enough elevation in the outer rail at the place of derailment, the car, following the well-known law, went off at a tangent, climbing the guard rail and running along a six-foot

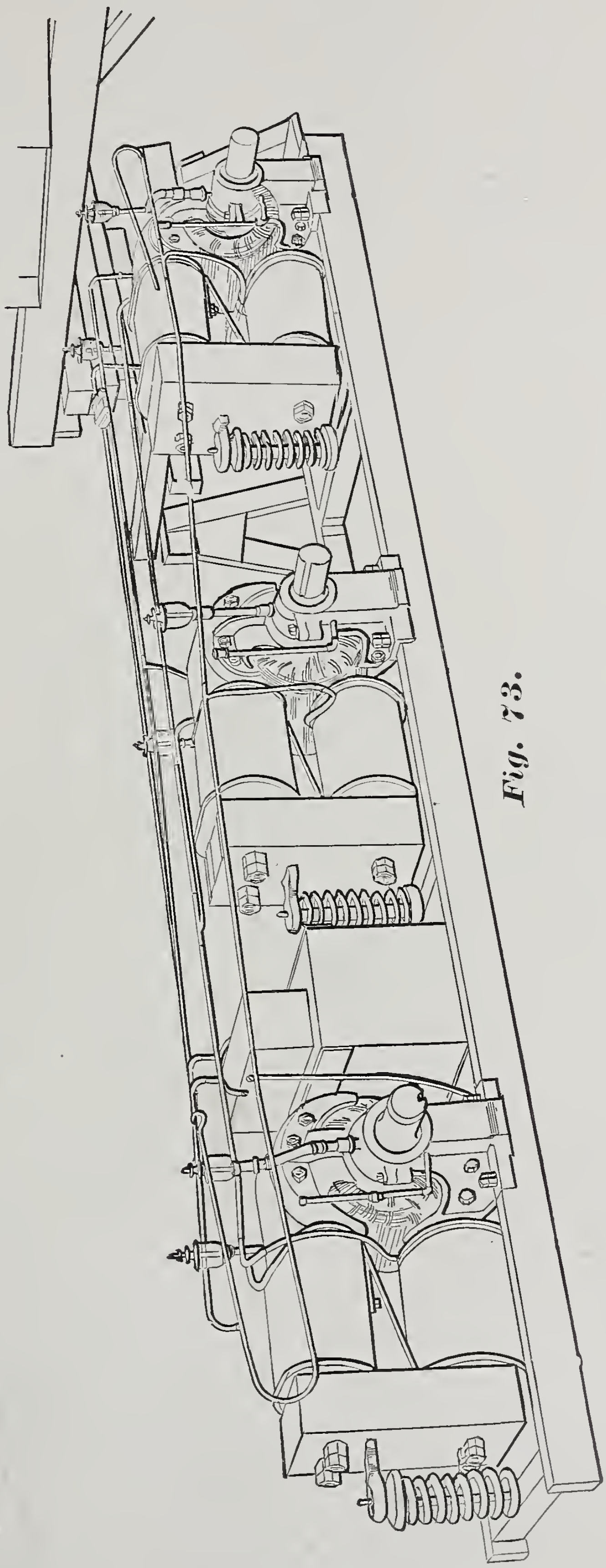


Fig. 73.

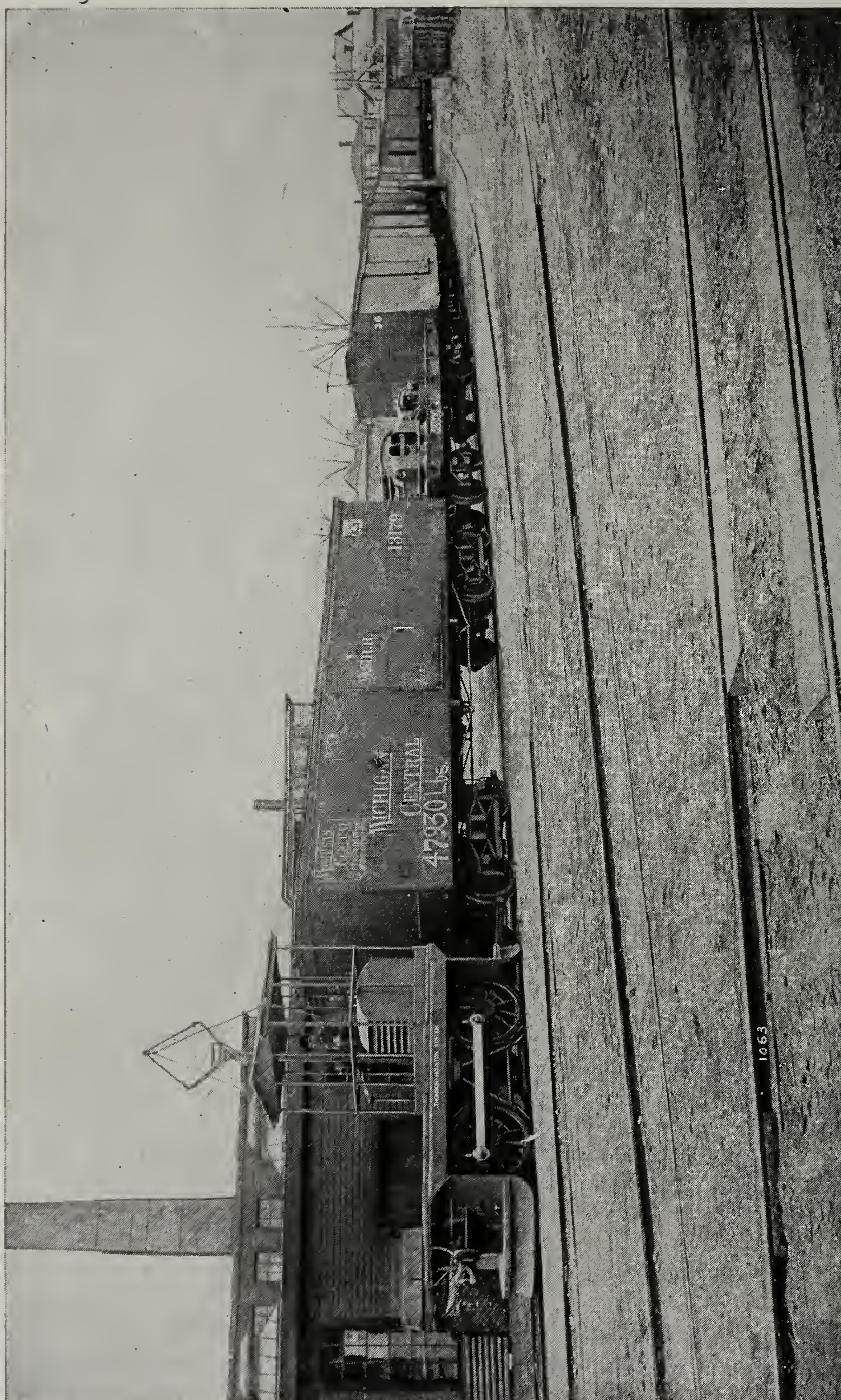


FIG. 74.

fill, and then out in a field a distance of about 1000 feet from the place of derailment. The car at this place was going at a speed of 115 miles per hour; the highest speed made, as taken between by two of the five observers stationed at intervals along the track, according to grade, being 118 miles. The longest continuous run was 22 minutes at various speeds, with a mean of 68 miles per hour; another run of 9½ minutes averaged nearly 80 miles per hour.

Owing to the small cost of track construction, the speed and time standard could not be kept up for any length of time, but no trouble was experienced with the phosphor-bronze bearings heating, as the oil was fed by a felt wick, as in standard street-car axle journals of the present day, and by a set-sight-feed oil cup on the top of the journal cap.

Certain values for atmospheric resistance were obtained, and which led to more extensive researches* by experiments with a "whirling machine" driven from the engine in the power house, and which coincided with the readings obtained with the traveling car. It will be seen that at the extreme low velocities the pressure is much greater than that by the law laid down by text-books, and at extreme high engineering velocities it will be found to be much less, but coincided with ordnance practice at low velocities. A speed of 86 miles per hour was made in England with the T. W. Worsdell compound locomotive. The total weight of the engine, tender, and train was 695,000 pounds; indicator cards were taken, showing 1068.6 H.P. on the level. At a speed of 75 miles per hour, on a level, and the same train, the indicator cards showed 1040 H.P. developed. Numerous high speeds of 86 miles per hour have been made in this country, with all of which American engineers are quite familiar.

By careful study the writer has been able to compile a table of train resistances on the level, wherein heavy rails and good track construction were the aim of the railroads making these speeds. The table gives the total resistances at various speeds and various exposed *area* to the atmosphere *per ton* of locomotive and train, using Trautwine's table of resistances for curves. Then the total resistances other than those due to the atmosphere were found to be at 120 miles, 20 pounds per ton of moving weight, and at 60 miles, 12.8 pounds per ton.

In the English run the total resistance at 86 miles was only about 12 pounds per ton.

The track construction for high-speed trains must be the very best that art can make it; the rails should be of very heavy weight, not less than 110 pounds, having carefully made joints, and all rails should be laid with joints *halved* and not laid *opposite*. My experience has shown this to be the best for high speeds. All rails should be laid on the best cross-ties of large horizontal or bearing surfaces, and not over 24 inches apart, center to center. The roadbed should be heavily ballasted with different sizes of stone; curves and small radii should not be allowed. It is important that on the outside of each rail a deep guard rail should be laid. The superstructure should be drained well. These are some of the most important features to be looked after in building a roadway for high speed. That the electrical companies see the importance of this class of work in the electrical line, and are gradually working up to it, appears from the fact that in street-car service we are getting into large units, and that there are splendid mining locomotives up to 150 H.P., and weighing from 400 to 425 pounds per horse-power, and that there are now in course of construction electric locomotives for a standard road. One of these has been in practical operation for some time past.

The following extract is taken from a report of one of the leading electrical companies:

"The continued success of the electric street railway, and the demands made by street railway companies for larger and more powerful motors to handle their cars, has led others interested in transportation to investigate the advantages of electric locomotion, with the result that not a few electric

*"An Experimental Study of Atmospheric Resistance," by O. T. Crosby. A paper read before the West Point branch of the United States Military Service Institute, 1890.

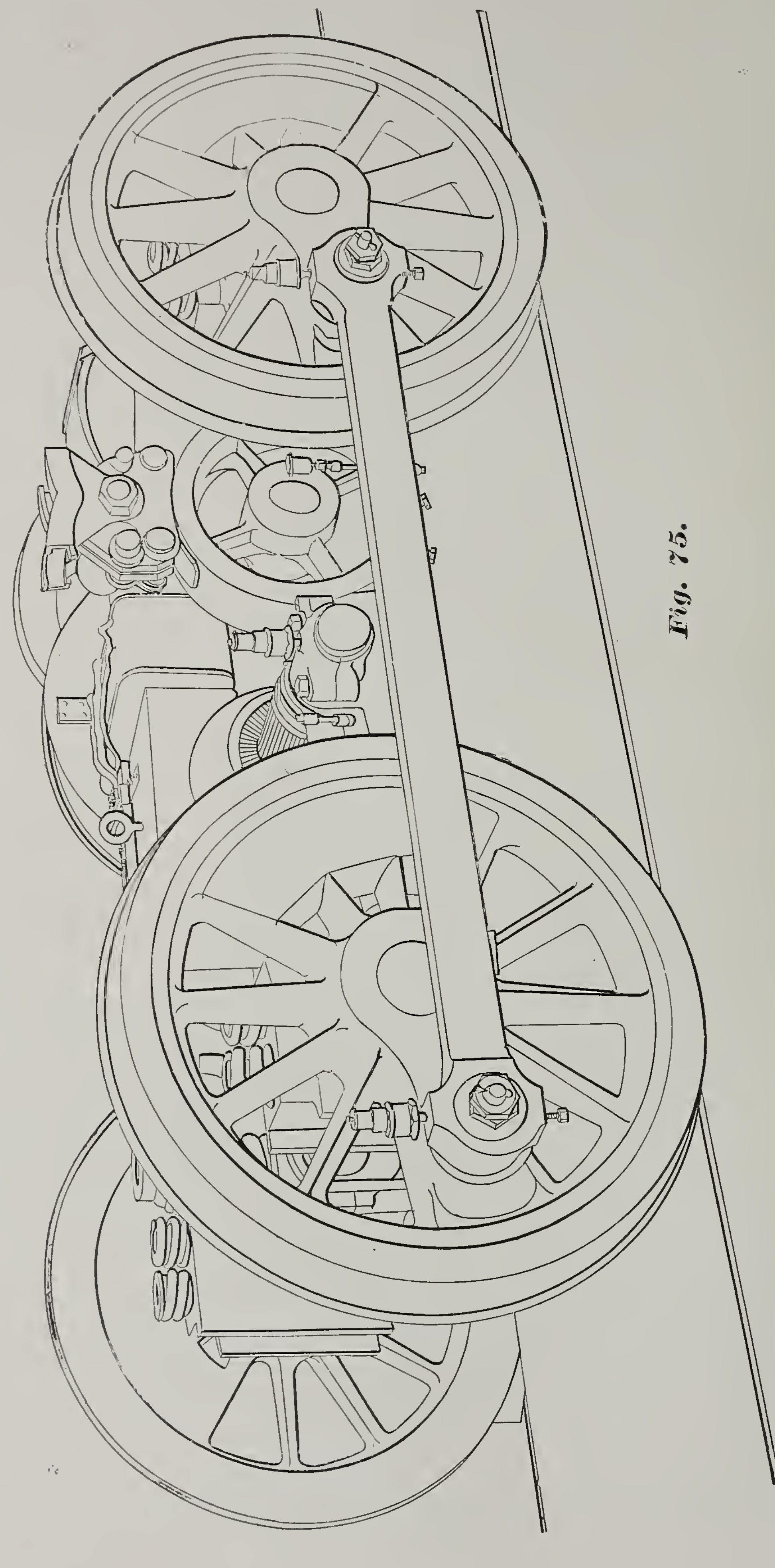


Fig. 75.

tramways are in operation throughout the country, hauling freight in our mills, factories, mines, etc. In this department of work, also, there has been a constant demand for more powerful machines, so that where the electric locomotive formerly hauled a few bales of cotton it is now called upon to handle a fair-sized train."

In compliance with the demands of this nature, one of the companies, some time ago, constructed an electric locomotive designed to obviate the necessity of employing a steam locomotive, and it may, indeed, be said to represent the *first large freight locomotive* displacing steam on a *standard gage railroad.* The locomotive is at present running at Whitinsville, Mass., carrying merchandise from the railway freight station to the works of the Whitinsville Machine Company's plant, a distance of 1½ miles. The locomotive is illustrated in Figs. 74 and 75. The power is furnished by a large generator located at the machine works, and conveyed over a trolley wire, from which it is taken by means of a universal trolley bar attached to the locomotive. The construction of the truck, etc., is well shown in the engravings, and is built in a square form in three castings, having also a platform for carrying loads, and cow-catchers and draw-bars at each end. The motor employed is one of what is called the "G" type of the Thompson-Houston Electric Company; the power is communicated from the armature to the rear axle by means of double-reduction gearing, and from the rear axle to the forward one by means of the side parallel rods. It will be well to state here that it is planned that all future freight locomotives should have the single-reduction type of motors. The motor consists of wrought-iron field magnets which are bolted to a magnetic yoke of mitis iron. One of these yokes carries the bearings which support that end of the motor on the axle, while the other yoke is spring supported from the other axle. This keeps the gears always in line and meshing correctly with each other, and at the same time provides considerable spring support for the motor, which in designing slow-speed locomotives should be looked carefully into, as well as in locomotives for extreme high speed. This is a matter of no small moment in designing such work. The gearing consists of aluminum bronze pinions and mitis iron spur gear wheels. This gearing runs in gear cases, in which a plentiful supply of grease is placed. This decreases the noise and friction, thus increasing the life of the gears very materially. On the intermediate shaft is heavily keyed a mitis-iron brake drum, which is covered with wood lagging. It is embraced by two half bands of steel, tightened upon it by means of the brake-drum lever, situated in the operating stand or cab.

The wheels are 42 inches in diameter, and are heavily steel tired. The frame consists of two heavy side plates in which are located the main axle bearing. Two heavy cast-iron plates, in which are cast the cow-catchers, are bolted to the side plates by means of heavy through bolts, which are a driving fit in reamed holes. These end plates carry the heavy spring draw-bars and bumpers.

The operating platform or cab is located at one end of the main platform, and is made of pipe framework and covered with a protecting roof. On this platform are located the lever for operating the controlling mechanism, the brake, and the double-acting sand boxes. The universal trolley bar also extends upward from the locomotive at this point, as shown.

The controlling mechanism consists of two large rheostats of the Thomson-Houston railway type. These are so arranged with their contact shoes that no reversing switch is needed. The operator stands so that he always faces the direction in which the locomotive is to go, and being in this position, he pushes the controlling lever from him to make the locomotive go forward, and pulls it toward him, past its vertical line, to make it go backward. A positive center notch or lock is provided, so that in turning the current off there is no danger of passing the neutral point on the rheostat, and so reversing the locomotive with the current on. When the operator stands in the above-mentioned position he pushes the brake lever from him in order to apply the brake. The steel bands are so arranged on the brake

drum that the friction tends to tighten them up more upon the wood lagging, and so assist the operator in braking the train.

The following data give the detail of construction of this locomotive, the construction of which has been under the direct supervision of the engineers at the works of the builders :

Wheel base, 6 feet 4 inches.
Diameter of wheels, 42 inches.
Speed reduction between armature and axle, 1 to 25.
Gage, 4 feet 8½ inches standard.
Wheel base, 6 feet 4 inches.
Measured height above rail platform, 4 feet 4 inches.
Greatest length of locomotive at cow-catcher, 15 feet 9½ inches.
Greatest length of platform, 12 feet 7¼ inches.
Greatest width of platform, 7 feet 1¼ inches.
Weight of complete locomotive, less trolley pole, 42,525 pounds.
Approximate of motor, 5400 pounds.

As in street-railway work, a combined main switch, lightning arrester, and fuse box is placed on the locomotive and within easy reach of the engine driver, so that he can instantly shut the current off from the locomotive by a slight movement of the hand.

The construction of the motor is of the most rigid and waterproof character, the field spools having their wire enclosed entirely, sewed up in canvas cases, which are covered with a heavy coating of water-proof paint.

The locomotive, which weighs 42,525 pounds, or about twenty-one tons, was designed to operate at 500 volts and to develop 100 H.P. at the draw-bar. This enables it to pull a train of six to twelve heavily loaded cars, or an aggregate load of 300 to 500 tons, at a speed of five miles per hour on a level with ease.

St. Louis enjoys the distinction of being the first city in the world to put in operation special electric cars devoted to postal and express suburban service. These cars are used on the St. Louis and Suburban road, and do both a city and a country business in handling mail matter. The route extends from Sixth to Locust streets, St. Louis, to Florrissant, St. Louis county, a distance of sixteen miles from the city, and the mail car supplies the above places as well as all the intermediate post-offices, as on our steam railroads. The car is 34 feet long, 8 feet 4 inches wide, and 11 feet 4 inches high, and has two four-wheeled bogie trucks mounted with two standard railway motors. The total weight of the car is 16,000 pounds. It not only carries the mails, but baggage, express packages, and dairy products ; it makes two trips per day per car.

It is encouraging to see the attitude that quite a number of our present leading steam railroads have taken in reference to installing a road with electric locomotives. The Northern Pacific and Wisconsin Central's name has been mentioned quite freely.

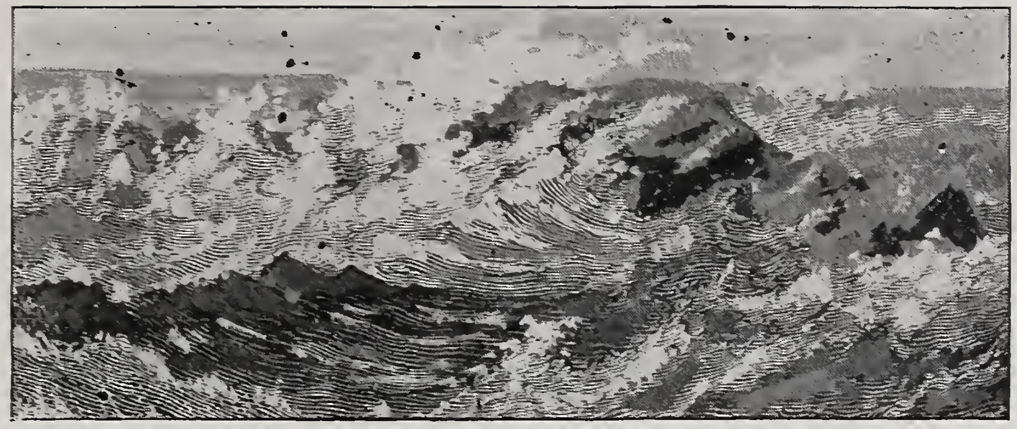
Dr. Wellington Adams and others of St. Louis, operating under the name of the Chicago and St. Louis Railroad Company, propose building an electric railroad between Chicago, Ill., and St. Louis, Mo., a distance of 250 miles, and maintaining a speed of 100 miles per hour with their trains. This work will be placed under the direct supervision of the most competent engineers in this line of work of the present day.

It is proposed to operate this road at night by the "block system through lights," as proposed by the Weems Company in their future road.

In conclusion, it is hoped that information given in this paper will be of interest. The question of resistances making up the total train resistances has been an open question ; it is needless to say that nearly all formulæ based upon past experiments, when applied to cases different from which such formulæ was constructed, and contained in our text-books, do not show the true value of such resistances.

The question of atmospheric resistances, when applied to a moving train at various speeds, is one which has been an unsettled question in the minds of all that have thoroughly studied past experiments in this direction. The table will be found convenient, as will also the table of total resistances.*

* "The Limitation of Steam and Electricity in Transportation," by O. T. Crosby. A paper read before the Am. Inst. of Elec. Engrs., May 21, 1890.



UTILIZING THE POWER OF OCEAN WAVES.*

By Albert W. Stahl, U.S.N.

AN intelligent study of the possibility and practicability of utilizing the power of ocean waves presupposes a thorough knowledge of the geometry and mechanics of wave motion. It is proposed, in this paper, to set forth the modern and generally accepted theory of such motion, so far as it applies to the subject in hand, and to deduce therefrom, if possible, the logical and most efficient method of utilizing the power of the waves; giving at the same time a brief description and criticism of methods heretofore proposed and employed.

While the motion of ocean waves in nature is usually quite complex in character, there are certain simple typical forms of such motion which have been satisfactorily studied, and the geometry and mechanics of which are well understood; and by making suitable combinations of these simple type-waves, the condition of more or less complex and irregular seas can be approximated to and their mechanics investigated with sufficient exactness for most practical purposes.

Prominent among the simple types of waves just referred to, and forming usually by far the most important element of actual ocean waves in nature, are those known as the deep-sea wave and the shallow-water wave. These are the forms of wave motion which occur in nature in a long series of waves, in which each successive wave is an exact reproduction of the one just preceding it, so that the wave goes on repeating itself indefinitely. While these conditions are rarely complied with exactly in nature, yet they are often very nearly so; so much so, that from a study of these two types and of their combinations, we can draw conclusions which are practically applicable to nearly all the motions of the sea.

The shallow-water wave is really the *general* case of regular trochoidal wave motion, the depth of the water entering as a factor in determining the shape and motion of the wave, while the deep-sea wave is only that *special* case of such motion in which the depth of water is so great that it no longer has any appreciable influence on the wave motion.

While it would thus be more logical to discuss first the more general case of the shallow-water wave, and to pass thence, by limitation, to the special case of the deep-sea wave, yet practically the much greater simplicity of the theory of the latter makes it preferable to reverse this order, taking up first the discussion of the deep-sea wave, and thence passing to the other and more general case. Our attention for the present will therefore be confined to the deep-sea wave, and the following discussion will be understood as referring to that wave except when otherwise specified.

Many and widely different theories of wave motion have been advanced from time to time, of which it is here only necessary to state that the older theories

* From paper read before the American Society of Mechanical Engineers.

are now definitely set aside as erroneous; and that the modern or trochoidal theory is generally accepted as very closely representing the actual phenomena which occur in nature.

Before entering on the explanation and discussion of the trochoidal theory of wave motion, it will be well to note the conditions which must in all cases be satisfied by any correct theory:

(1) The condition of dynamical equilibrium, which expresses the general law of the motion of liquids, that the effective force acting on each particle to produce acceleration is the resultant of its weight and the pressure of the surrounding liquid.

(2) The condition of continuity, which expresses the fact that the mass of each elementary volume fixed in space within the liquid is constant.

(3) The boundary conditions, which are in general the depth and conformation of the bottom, the extent of the surface of the liquid and the state of pressure on the same. For our purposes the depth is assumed as infinite or so great as to have no appreciable influence, and the same assumption is made as to the extent of surface. The pressure on the surface is assumed to be uniform.*

(4) Conditions of formation.—Any theory which satisfies the three foregoing conditions is a *possible* theory of wave motion, the applicability of which to the motion of ocean waves in nature must be further tested by the conditions of formation of such waves. This generally involves some estimate of the viscosity of the actual liquid, as well as its condition as to molecular rotation, and of the possibility of producing such motion from a state of rest by the action of the wind.

We shall find that all of the above conditions are practically satisfied by the trochoidal theory both as to the deep-sea and shallow-water waves; so that the conclusions to be drawn therefrom may serve as a basis for any investigations whose object is the practical utilization of the power inherent in such waves.

The trochoidal theory of the deep-sea wave refers, then, to a regular and uniform series of equal waves in deep water, and is best explained by dealing at first with the surface particles of the wave only, for which its principal features may be stated as follows:

Each particle of water revolves with uniform speed in a circular orbit, the plane of which is vertical and perpendicular to the wave ridge or crest. Each particle makes one complete revolution during the time in which the wave advances through its own length.

The diameters of the orbits of all the surface particles are equal.

The successive particles along the wave are in successive phases of their motion, the particles of the crest of the wave being at the top of their orbits and moving in the same direction as the wave itself, and the particles at the trough being at the bottom of their orbits and moving in a direction opposite to that of the wave.

Many observations of ocean waves have been made, especially by officers of the French and English navies; and, without entering on the details of their results, it may be broadly stated that the theoretical relation between velocity and length, which was shown to be one of the test conditions of the trochoidal theory, has been found to practically agree with that actually observed in ocean waves in nature.

Many experiments have likewise been made on artificially formed waves; and among such experiments those of the Weber brothers are best known and specially important, on account of the great care and ingenuity displayed and the large number of observations made.

The experimental tanks used by the Webers were between 5 and 6 feet long,

* Since the surface of the liquid is in contact with the atmosphere, it is not strictly a free surface, but rather the surface of separation of two fluids, the one liquid and incompressible, and the other gaseous and compressible, and generally having some motion relatively to the wave form. It seems a necessary consequence that by the passage of the long series of waves contemplated by the trochoidal theory, the air must experience a tendency to set up a corresponding wave motion, possibly influencing the condition of pressure at the surface of separation. The uniformity of pressure above assumed may thus not be strictly correct, though the error due to the cause just explained must necessarily be extremely small.

8 to 30 inches deep, and half an inch to an inch wide, the sides being wholly or partly made of glass. They experimented with various fluids, but the results of greatest interest to us are those obtained with water containing a great number of floating particles of the same specific gravity as water. By observing the movements of the particles with the naked eye, or, when necessary, with the microscope, the motion of the particles of water throughout the whole depth was successfully studied. The waves were generated by plunging a glass tube into the water, raising the latter to a certain level in the tube by suction, and then allowing it suddenly to drop.

The profile of the front of the wave was satisfactorily obtained by placing a slate sprinkled with flour in advance of the coming wave, and then suddenly withdrawing the slate as the wave was sweeping along it, the water removing the flour from the immersed portion of the slate. Attempts to obtain the profile of the back of the wave by suddenly plunging the prepared slate into it were not so successful.

The results of their many experiments were embodied by them in the following conclusions: When a crest is followed by an equal trough, every particle moves in a curve which, as near as the eye can judge, is an ellipse with its major axis horizontal; the motion of the particle when in the highest part of the ellipse being in the same direction as the motion of the wave, and in the opposite direction when at the lowest part of the ellipse. At different depths the motion was found to be different, the horizontal motion being diminished in some degree for the deeper particles, and the vertical motion being very much diminished, so that in approaching the bottom the ellipses became very flat, being almost indistinguishable from a horizontal straight line. It was also found that different particles in the same vertical described corresponding parts of their orbits at the same instant of time.

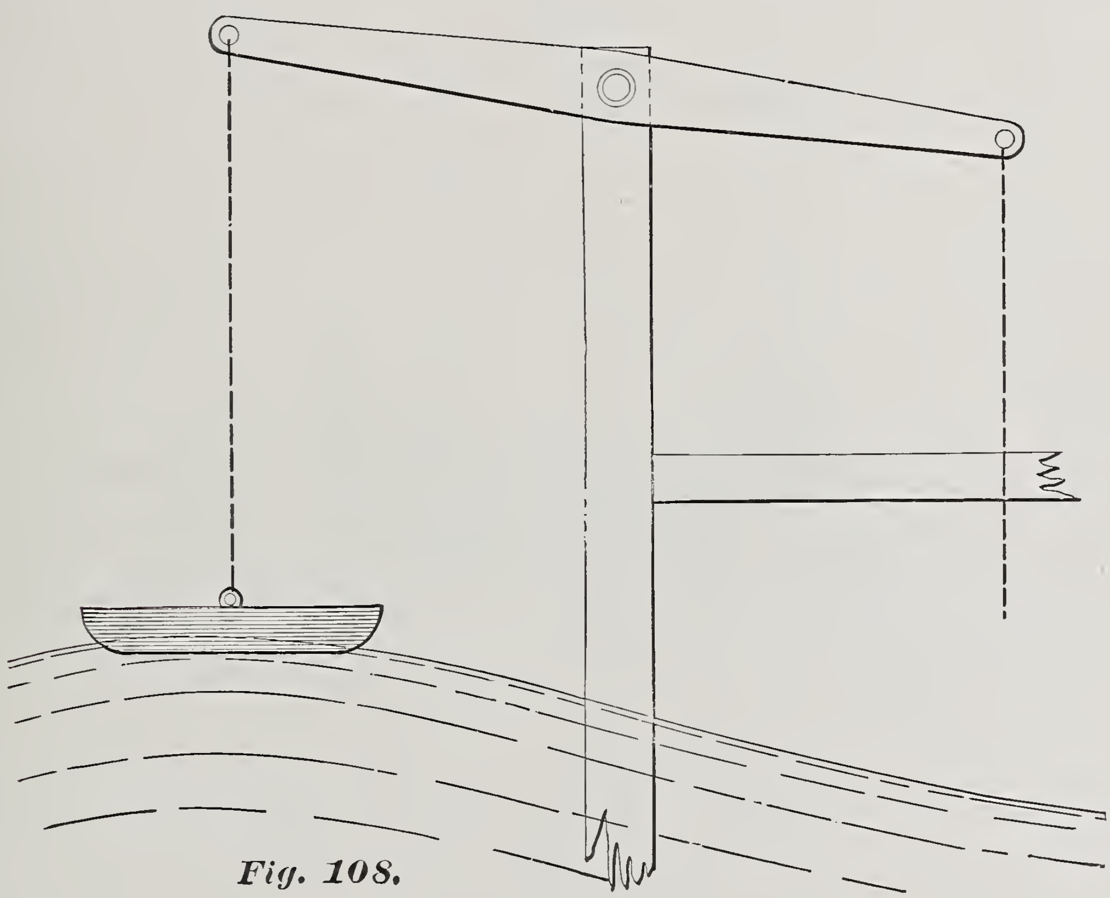


Fig. 108.

The general velocity of the wave was found to increase with the depth of the fluid and with the size of the wave.

Their work seems to have been done without regard to any particular theory, and the verifications by their experiments of our theoretical results already obtained is thus specially valuable. The contrivance of using a vessel with

glass sides and observing the motions of floating particles is one so admirably adapted to overcome the greatest of all the difficulties attending the comparison of a wave theory with experiment, namely, that of ascertaining the laws of movement of individual particles, that these experiments must be accorded a deservedly very great importance.

Taking up now the question of the practical utilization of the energy which we have found to exist in ocean waves, and which for large waves reaches an enormous figure, the subject naturally divides itself into several parts:

4. Storage arrangements for ensuring a continuous and uniform output of power during a calm or when the waves are comparatively small.

Taking up first the consideration of the motions that may be utilized for power purposes, we find the following:

1. Vertical rise and fall of particles at and near the surface.
2. Horizontal to-and-fro motion of particles at and near the surface.
3. Varying slope of surface of wave.
4. Impetus of waves rolling up the beach in the form of breakers.
5. Motion of distorted verticals.

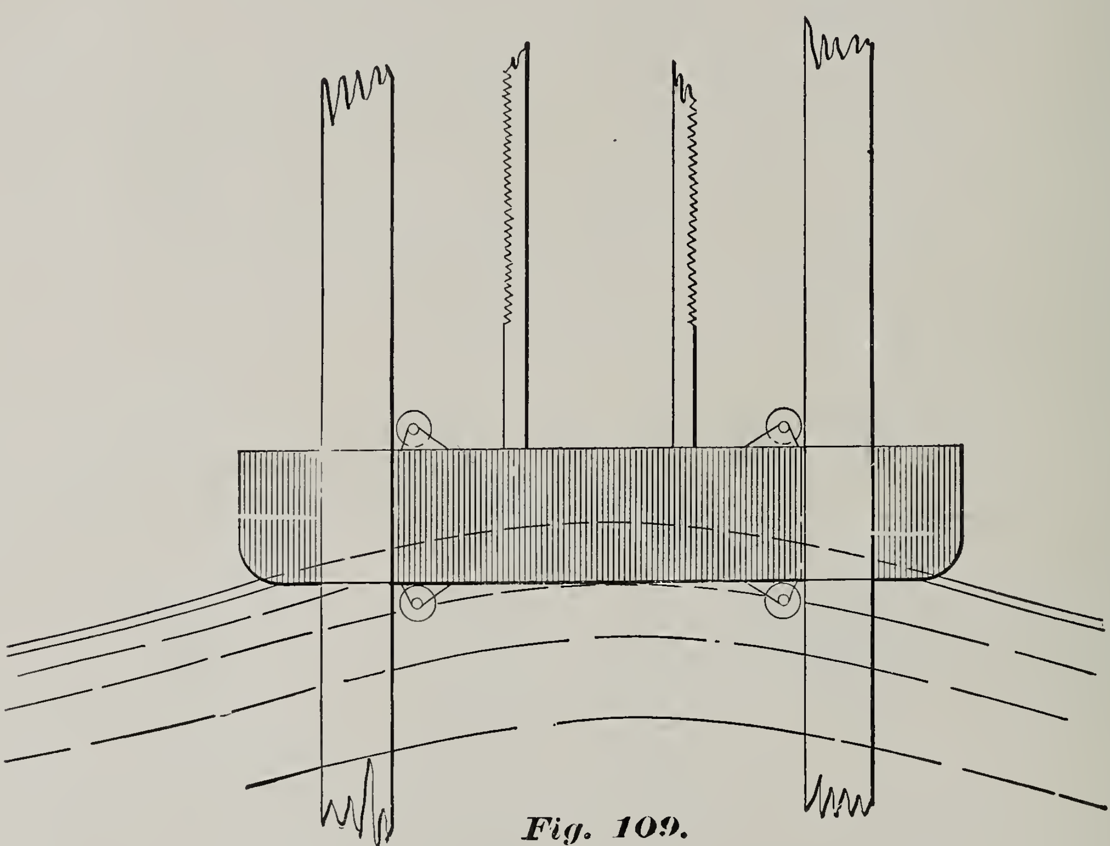


Fig. 109.

1. The various motions of the water which may be utilized for power.
2. The wave motor proper. That is, the portion of the apparatus in direct contact with the water, and receiving and transmitting the energy thereof; together with the mechanism for transmitting this energy to the pumping or other suitable machinery for utilizing the same.
3. Regulating devices, for obtaining a uniform motion from the irregular and more or less spasmodic action of the waves, as well as for adjusting the apparatus to the state of the tide and condition of the sea.

All of these motions, except the last one mentioned, have at various times been proposed to be utilized for power purposes; while no attempts seem to have been made to utilize this last-mentioned motion, that of the distorted verticals, which seems the one by far most likely to give efficient results, as will be presently explained.

The wave-motor proper, that is, the portion of the apparatus in direct contact with the water, together with its mechanism for transmitting the energy to the machinery provided for the utilization thereof, may be best examined at the same time with the particular mo-

tion of the wave which it is employed to utilize.

The first motion we have mentioned is that of the vertical rise and fall of the particles at and near the surface. The most rational way of utilizing this motion and the one almost invariably proposed, is by means of a heavy float. The float is either permitted to have a small amount of side motion, the extent of such motion being limited by the length of chains connecting the float to anchors, piles, or other fixed structures, or it is guided in a vertical straight line, or in the arc of a vertical circle. The float is usually hollow, being ballasted if necessary with rock or other heavy materials. It is usually rectangular and flat, or in the shape of a sphere, an ellipsoid, or a cylinder. In Fig. 108 is shown a simple case, the float being secured to a rope which is attached to one end of a walking beam, the other end of the latter being connected by a second rope to suitable mechanism for utilizing the power. As the float rises on the wave, the slack of its rope is taken up by suitable ratchet arrangements, and when the wave falls, the weight of the float is available for the production of useful work. In Fig. 109 the float is guided by guide rollers traveling along vertical piles. This float is provided with vertical straight racks which transmit their motion to pinions located on the structure above. The racks being rigid, power can be taken off on both the up and down strokes, though of course no increase of power is thereby gained over the simple scheme of taking off the power during the down stroke only. In Fig. 110 is shown a very simple device, a cylindrical float rising and falling on a central guide pile, the power being transmitted by means of vertical racks. A modification of this has the pump, which is operated by the rise and fall of the float, in the upper part of the guide pile itself, the object being to get all the principal parts as nearly as possible in line. In Fig. 111 is shown an ellipsoidal float, held at one end of a frame, the other end of which is pivoted to a rigid structure at some point above the water. The motion of the float is transmitted by a rope to suitable pumping mechanism. This device is practically employed at some points on the Eastern coast to pump

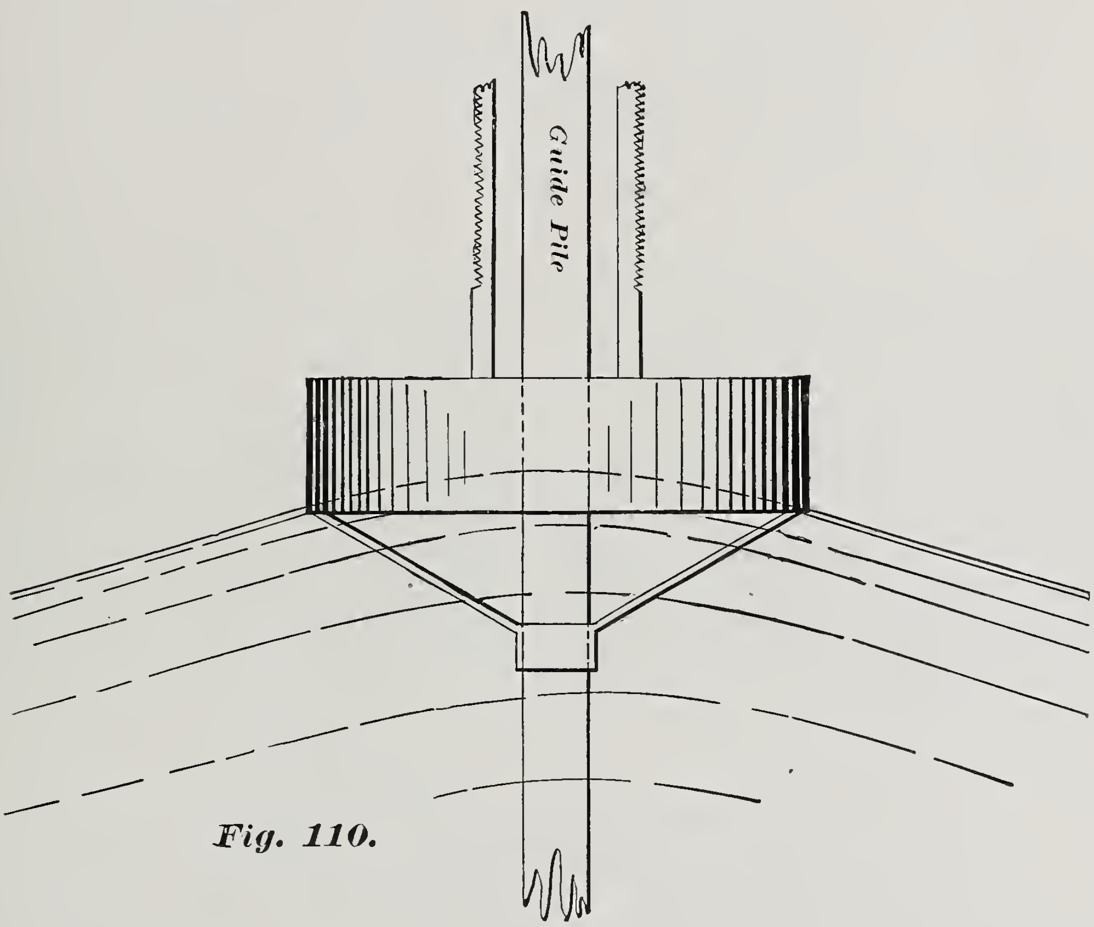


Fig. 110.

salt water for street sprinkling purposes. Fig. 112 shows a somewhat similar arrangement, the frame carrying the cylindrical float being pivoted below the surface of the water, and the shaft to which the frame is attached actuating suitable mechanism by means of a geared sector. This float is, in addition, provided with a curved lip to somewhat confine the water and thus get the full benefit of its momentum. In Fig. 113 is shown a spherical float attached to a rope leading downward. The actual rise and fall of the float causes a corresponding motion of the rope, which leads through a sheave below to proper mechanism on shore. The spherical float shown in Fig. 114 is anchored by means of a rope leading downward and through a sheave to the shore. As the float is forced upward by the rise of the wave, it is also compelled to approach the vertical line passing through the lower sheave, and thus causes a pull on the power rope, the power being thus transmitted by a sort of toggle-joint arrangment, the efficiency of which, to say the least, is doubtful. The main objection to floats operated by this vertical motion of the water may be briefly stated. In the first place, the quantity of power that can be obtained by a float covering any given area of water, and rising and falling through a certain distance, is directly proportional to the weight of such float, as the number of foot-pounds of energy for each wave is simply the weight of the float in pounds multiplied by its rise or fall in feet.

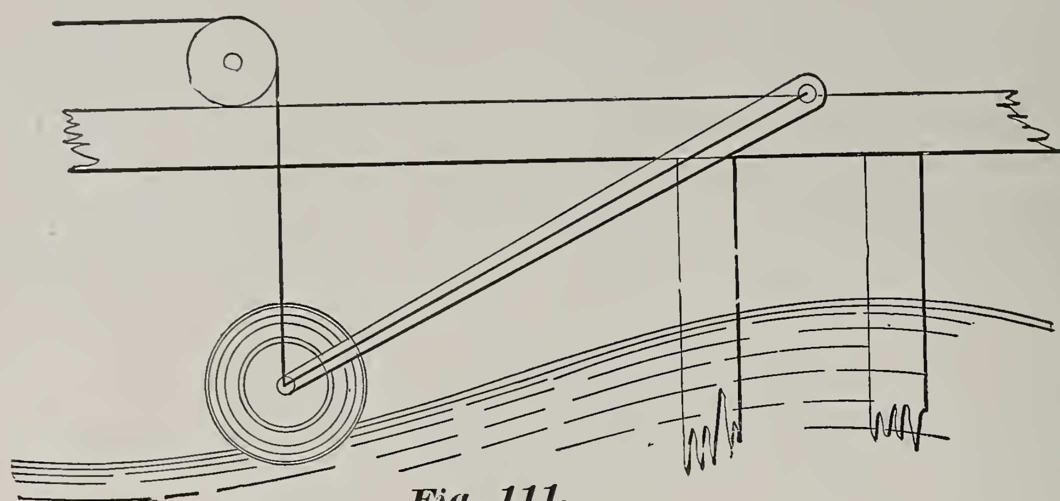


Fig. 111.

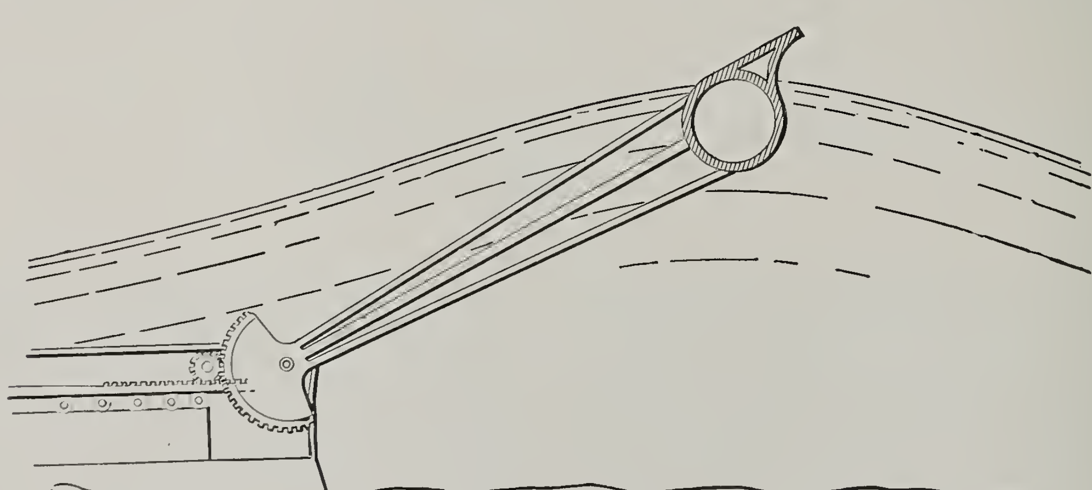


Fig. 112.

With a wave of given height, then, the amount of power obtainable from such float can only be increased by increasing the weight of the latter. This weight may be increased in either of two ways—(1) By making the float heavier per square foot of water area covered,

as by using heavier material, or by increasing the amount of ballast carried. (2) By keeping the weight per square foot unaltered, but increasing the area of water covered by the float. Either of these methods is, however, attended with a loss of efficiency. An increase in weight of float means an increase in submerged depth and in inertia ; and the inertia of such heavy float could not be overcome with sufficient rapidity to cause it to rise to the whole height of the wave, thus decreasing its efficiency. If, on the other hand, the float be made light to reduce its inertia, the possible amount of power to be transmitted thereby would again be correspondingly decreased. Furthermore, as the area of water covered by such float is made greater, the particles of water in contact with different points of its length would be in different phases, so that the *mean* rise of such water would be less. Thus it is evident that if the float were just half as long as the wave, it would have a tilting motion, but no rise or fall as a whole whatever ; and if it were longer than the wave, practically no power at all could be obtained thereby. But as the length of the waves varies from day to day, a float which would be fairly efficient on one day with a certain series of waves might be utterly inefficient with a series of waves of a different length some other day.

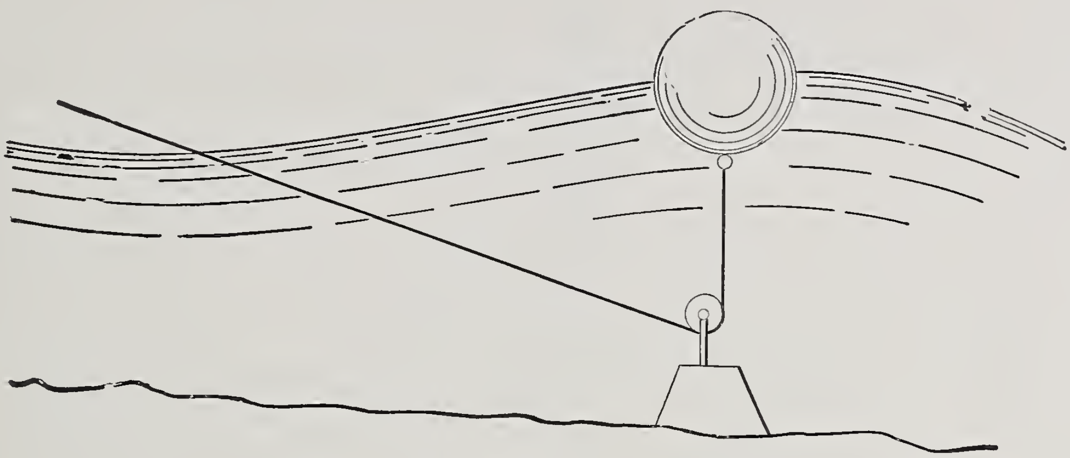


Fig. 113.

The next motion to be considered is the horizontal to-and-fro motion of particles at and near the surface. The simplest arrangement for utilizing this motion consists in suspending a vertical flat vane from some point above the water, the lower end of such vane dipping into the water to a certain limited depth and being actuated by the horizontal component of the motion of the particles at and near the surface. Such arrangements are shown in Figs. 115 and 116, the vane in the latter actuating suitable mechanism by means of a connecting-rod attached to its prolongation above

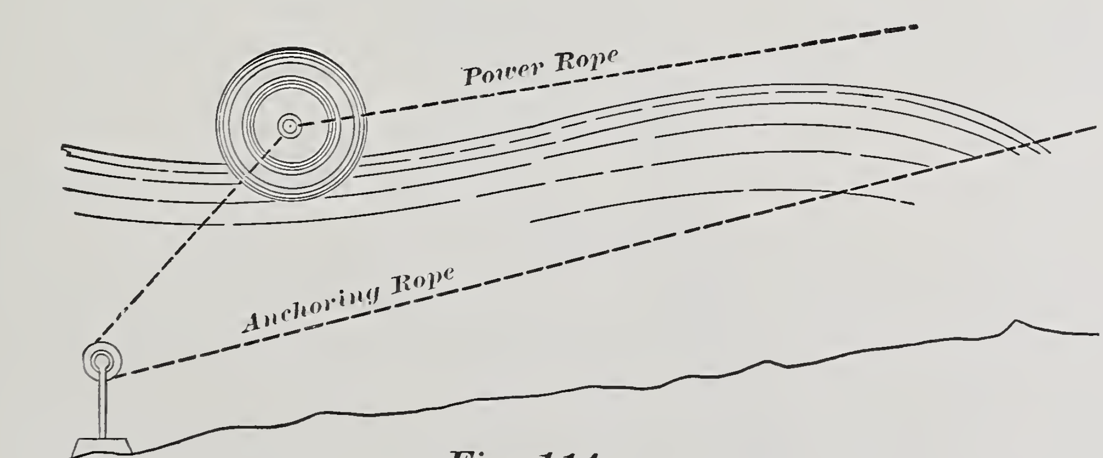


Fig. 114.

the point of support, while in the former it operates a submerged pump directly, by means of a connecting-rod attached to its lower end.

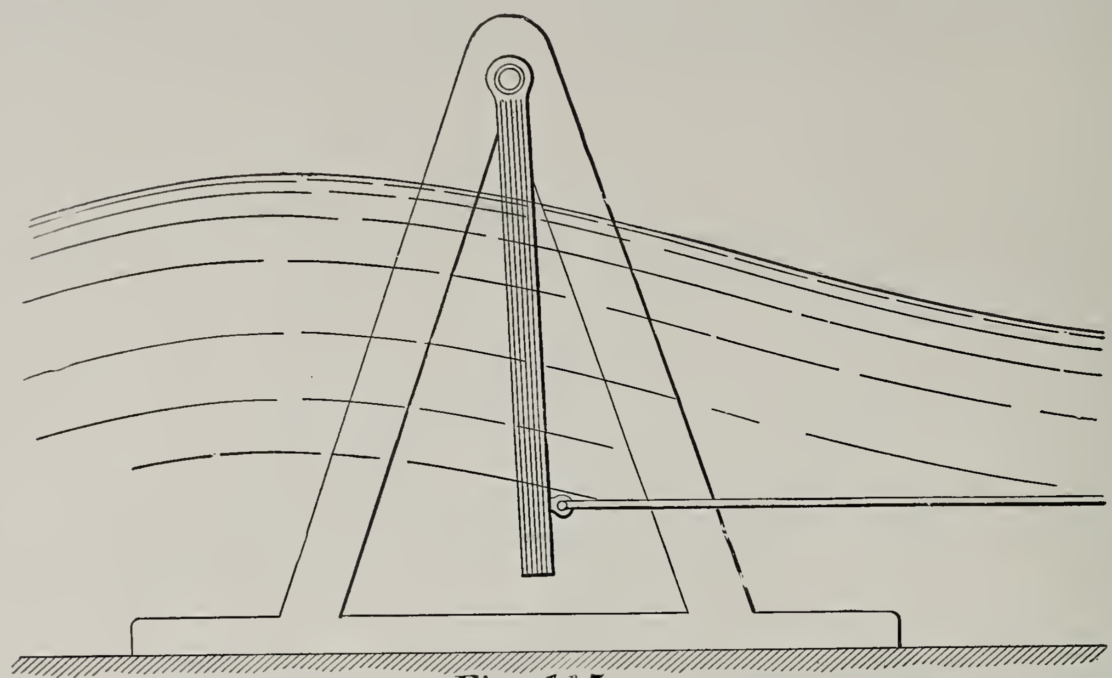


Fig. 115.

That some power can be obtained by these devices is beyond question, but their efficiency is hampered by the fact that while at first sight it would seem that the amount of power thereby obtained would, with a given breadth of vane, be directly proportional to the depth of immersion of the lower end of the vane, yet it is evident that the deeper the immersion of the vane the less efficient the apparatus would be. For the vane has an angular motion about its point of support, its lower immersed end moving through a greater distance than the portion at the surface of the water. But we have above seen that the horizontal motion of the particles is greatest at the surface and becomes less as the respective particles are further below the surface. The relative motions of the upper and lower portions of the vane are thus exactly the reverse of the natural relative motions of the particles of water in contact with those

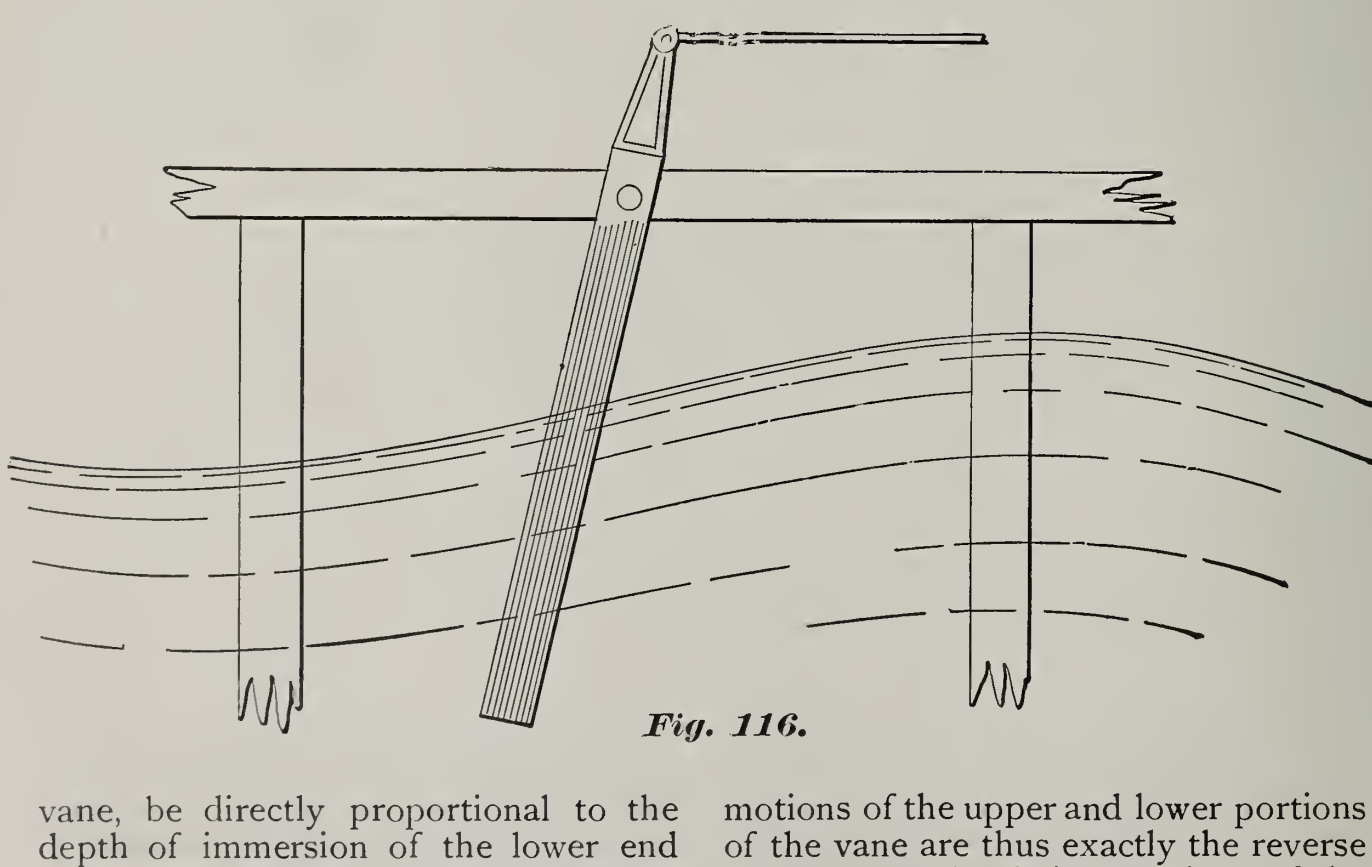


Fig. 116.

portions; so that as such vane extends deeper into the water it becomes less efficient. If the vane be extended to the bottom, its motion would be much reduced in the case of a shallow-water wave, and it would come to an absolute standstill in the case of the deep-sea wave. Instead of the vanes just described, it has also been proposed to employ a float, rigidly secured to a long arm extending to and pivoted at some point of a fixed structure overhead or extending downward and pivoted at some point near the bottom of the water, but in each of these cases the utilization of the motion of the surface particles only is contemplated. A somewhat more complicated arrangement is shown in Fig. 117, in which a peculiarly shaped float is supported by crossed suspension rods. The longitudinal concavities of the surface of the float are alleged to be "of substantially the form the waves assume as they approach the shore, so that the full force thereof is utilized better than if sharp corners were presented."

In Fig. 118 is shown an arrangement of a cylindrical float, suspended by a number of ropes attached to the float at such points as to utilize not only the rise and fall of the float, but also the horizontal to-and-fro motion of the same. The extreme motion of the float is limited by chains attached thereto, as shown.

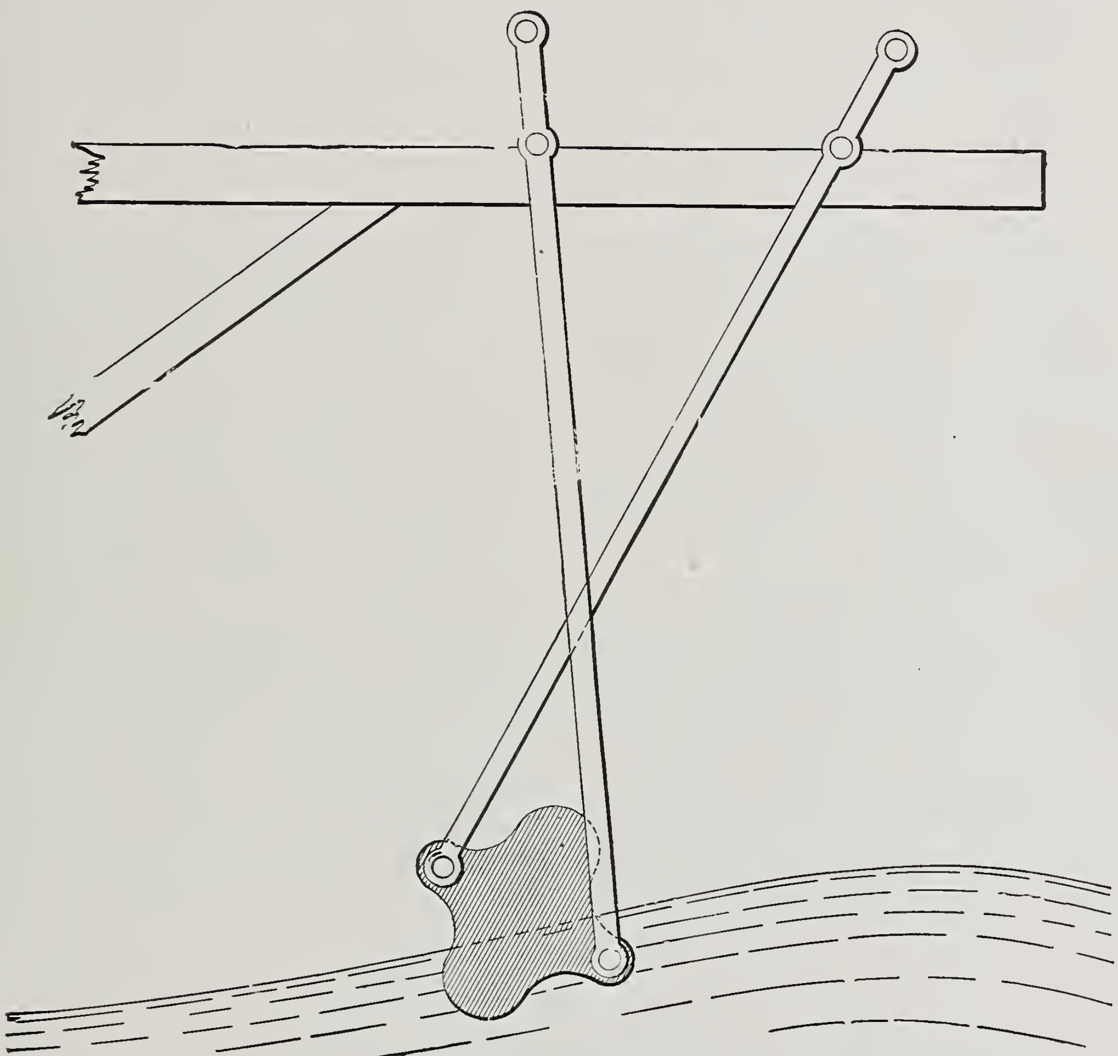


Fig. 117.

The next motion to consider is that due to the varying slope of the wave. In Fig. 119 is shown a float which lies on the wave and changes its inclination to the horizontal in accordance with the varying slope of the wave. A rigid arm is firmly secured to the float, extending across the latter; and ropes attached to the upper and lower ends of this arm transmit the power to mechanism on the shore or on a suitable structure erected in the water near the shore, the float

itself being prevented from moving shoreward by an anchoring rope. The objections to this scheme are two-fold. In the first place, the curves in which the power ropes hang have different deflections according to the strain to which they are subjected. As the float becomes inclined by the action of the wave slope, the strain on one of the ropes increases, while that on the other decreases, the deflection of the former becoming less and that of the latter becoming greater ; and the change in deflection corresponding to any increase in strain must be produced before the latter can be transmitted. The motion of the float must thus first take up a certain amount of slack in the rope, so as to decrease its deflection to that corresponding to the strain to be transmitted ; but unless the waves were very steep, the motion of the float would probably hardly suffice to do more than take up this slack ; and in such case no power, or at any rate very little power would be transmitted. This defect in the arrangement could, however, be much lessened by placing the float much nearer the structure supporting the mechanism, so that shorter ropes or even rods could be employed for transmitting the power. But there is another and more vital objection. To obtain the largest amount of power from this arrangement, the float should be exactly half the length of the wave. But as the waves vary considerably in length from day to day, it follows that the float, while quite efficient in waves to which its length was suited, would lose efficiency among larger waves and come

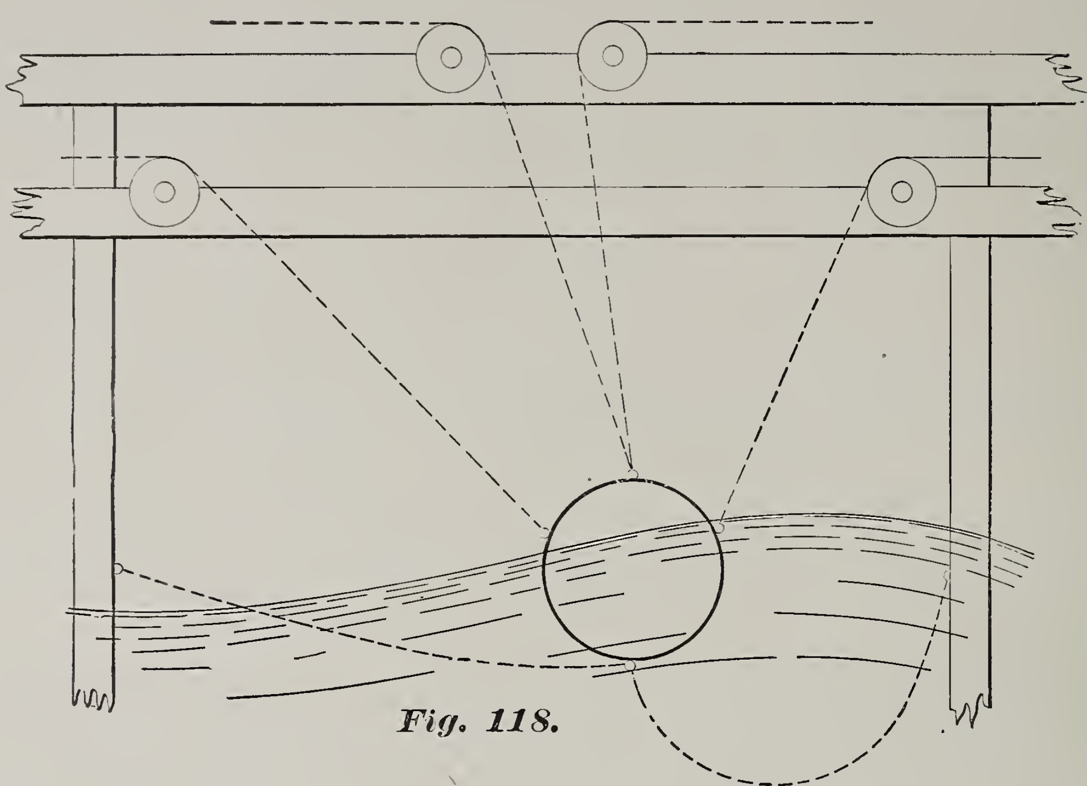


Fig. 118.

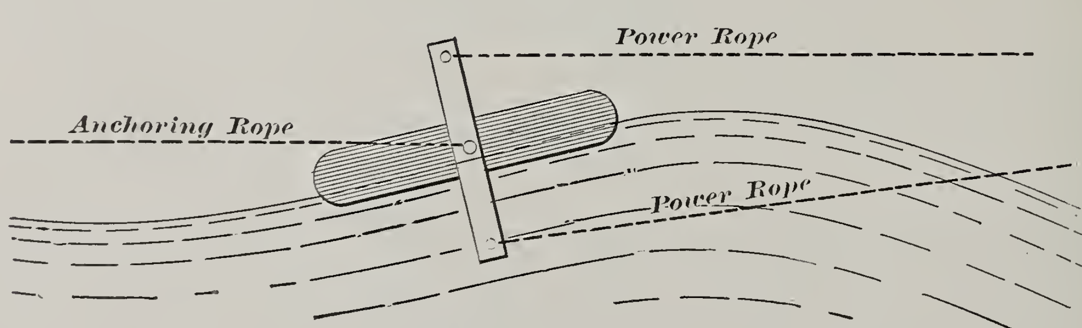


Fig. 119.

almost to a standstill among much shorter waves.

Somewhat akin to the above is the device proposed for employing the varying angle between two portions of the surface some distance apart in the direction of the length of the wave. It consists of two floats (Fig. 120), preferably pontoons containing the mechanism for utilizing the power, these floats being hinged together so as to be capable of motion relative to each other about a horizontal axis. As the floats ride on opposite sides of the crest of a wave, their outer ends are lower than their inner ends, while in the trough of a wave this condition is reversed. The angular motion of the floats relative to each other is employed to operate a ratchet-wheel as shown, from which the power is transmitted to any suitable mechanism.

The difficulty with this device is also due to the varying length of the waves from day to day. It is evident that if the length of the floats or pontoons be too short in comparison with the length of the wave, the angle between them will be very slight, and but little power will be obtained. On the other hand, if they are too long, the angle is again diminished, and the same difficulty presents itself. Thus a pair of such pontoons, of proper lengths to give their greatest efficiency for a certain length of wave, would be much less efficient for a wave one-half as long or double as long.

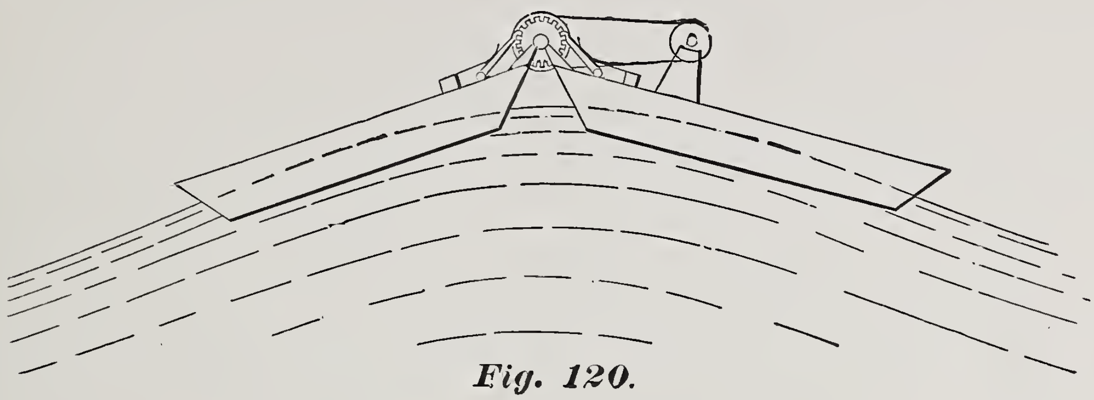


Fig. 120.

In Fig. 121 is shown an arrangement for utilizing all three of the motions above discussed. It consists of a rectangular float, surmounted by a framework rigidly attached to the same. A number of ropes are attached to various points of the float and of the framework as shown, leading over sheaves so placed that power will be transmitted, not only by the rise and fall of the float, but by its tilting action on the slope of the wave, and by its horizontal to-and-fro motion. While superior, in some

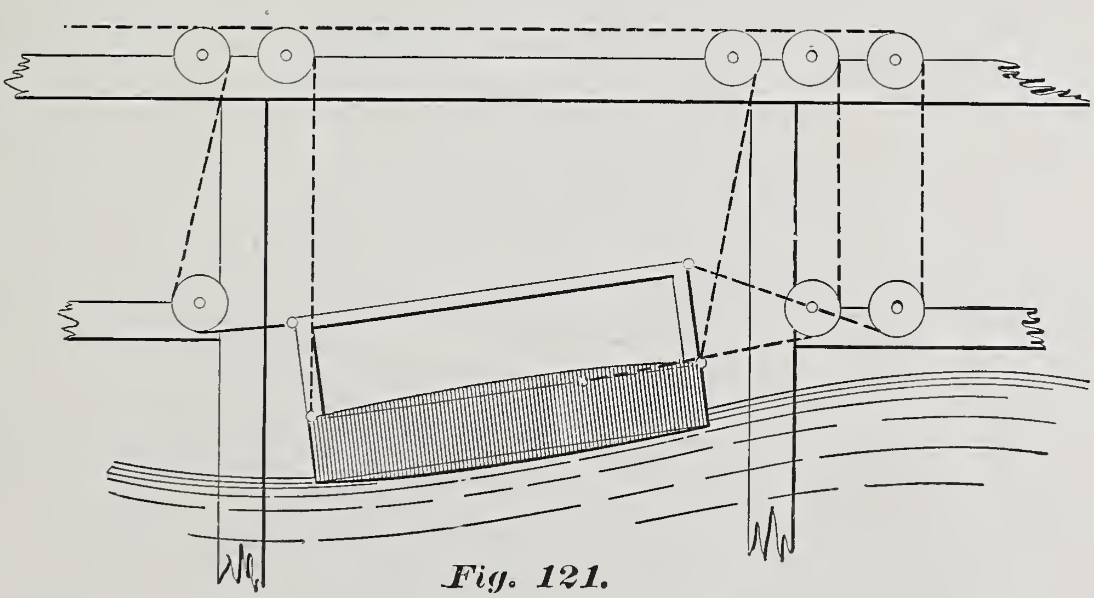


Fig. 121.

respects, to some of the simpler schemes above explained, it partakes of many of their disadvantages, and has the additional one of being somewhat more cumbersome and complicated.

Several radically distinct methods have been proposed for utilizing the impetus of breakers rolling up the beach. In Fig. 122 is shown a nearly vertical vane held in a framework which is provided with wheels at the bottom and with ropes leading to suitable mechanism on shore. These wheels run on rails laid down the slope of the beach, or may even run on the slope of the beach itself, if the latter be hard and smooth. As the breaker strikes this vane, it drives it rapidly up the slope of the beach, and the slack of the rope is taken up by suitable ratchets or other contrivances. As the water recedes, the weight of the vane and carriage causes the latter to run down the slope of the beach, and useful work may be performed by utilizing the pull on the rope. Some little difficulty would probably be experienced with this apparatus on account of the sand filling in along the track, which would probably finally result in throwing the apparatus off the track. It labors under the disadvantage that much of the inherent energy of the smooth waves is dissipated in the eddies of the breakers before it reaches the vane, and that the delivery of the energy of the breakers to the vane by what would practically be a sharp blow is naturally much less efficient than in cases where this transfer of energy is more gradual.

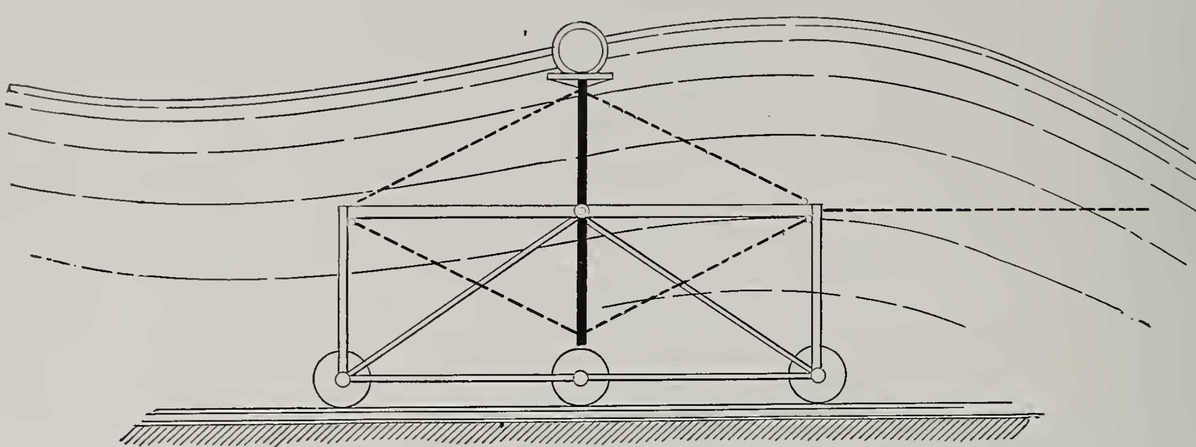


Fig. 122.

An entirely different method is shown in Fig. 123. The mass of water is allowed to enter a large strongly built chamber, which decreases in both height and width toward its shoreward end. At this end a non-return valve *a* is provided, beyond which is a closed chamber. In the top of the latter is the non-

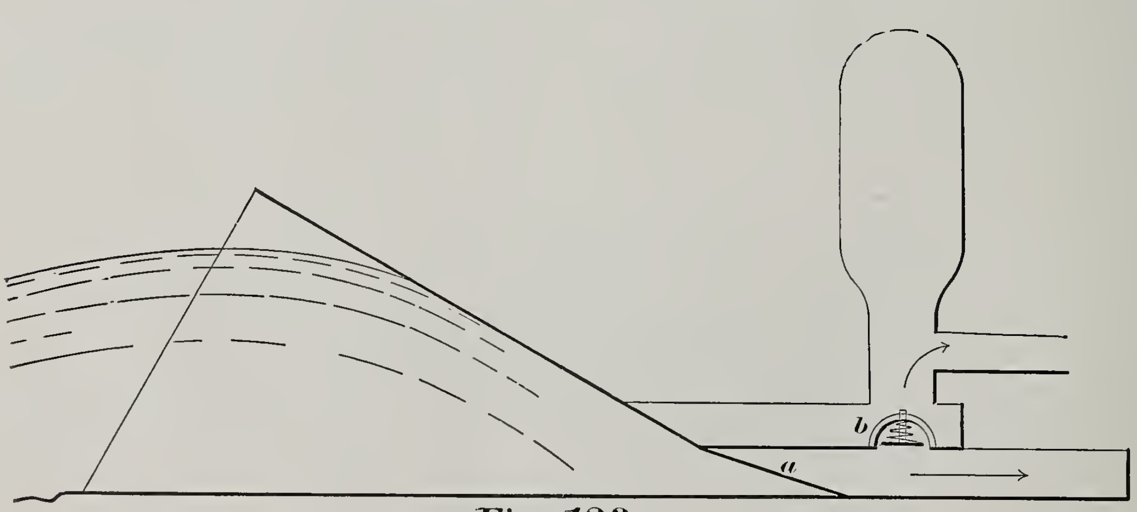


Fig. 123.

return valve *b*, above which is an air chamber and a pipe leading to the water reservoir. When the wave enters the receiving chamber it has a certain velocity; and as the cross-sectional area of this chamber becomes less, the velocity of the water must increase until at the inner end it becomes sufficient to pass through the non-return valves *a* and *b*, against the pressure due to the height of the water in the reservoir. While this apparatus has the advantage of simplicity and few working parts, it labors under the disadvantage that much of the energy of the waves is dissipated by the time they reach the apparatus. There is also much internal friction and great liability to filling up with sand. It has the further disadvantage of not being adjustable to rise and fall of the tide or the condition of the sea.

Having now briefly considered the principal methods hitherto proposed for utilizing the power of the waves, and examined into the causes of any inefficiency that may have been found to exist, we will next take up the consideration of the utilization of the motion of the distorted verticals; and as this motion seems the one most likely to give efficient results, we shall discuss the same at length.

In accordance with the principles just set forth it has been proposed jointly by the author and the late Mr. Richard Gatewood, U. S. Navy, to utilize the movements of the distorted verticals by opposing thereto movable vanes pivoted or supported either at their ends or other points of their lengths, so as to move in general accordance with the motion of the distorted verticals, and thus to receive and transmit the maximum effect of the wave movement.

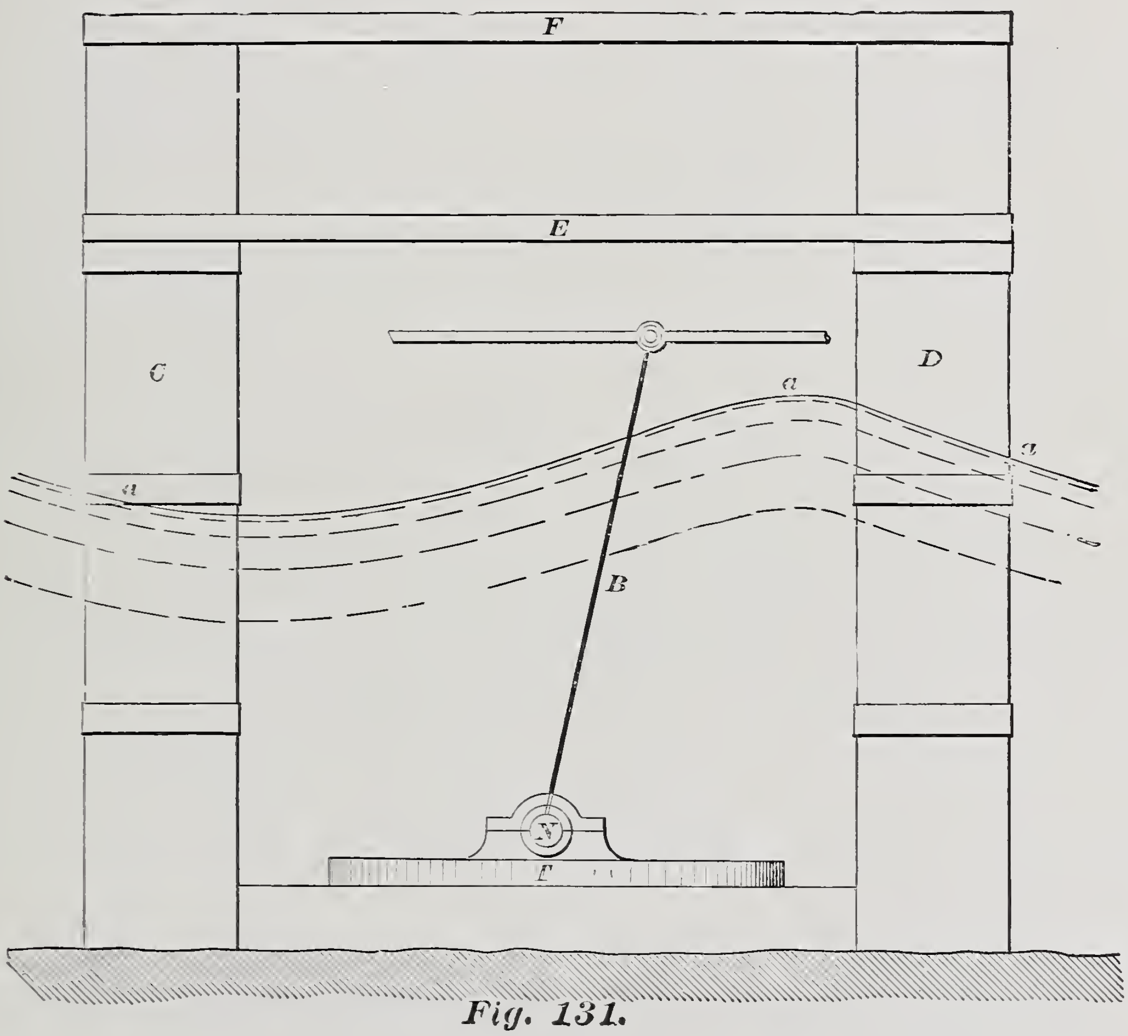


Fig. 131.

The preferable method of suspending the vane, in any actual case, depends on the depth of the water and on the range of variation in the usual magnitude and direction of the waves.

When the water is sufficiently deep to permit of nearly circular orbits for the particles of water, in which case the

motion near the bottom is very slight, the vane may be supported by and allowed to vibrate about a single horizontal axis passing through or near its lower edge, as the movement and general direction of the distorted verticals will, in such case, be sufficiently well followed by a vane suspended in this manner. In Fig. 131, *a a a* is the wave profile, and *B* is a vane arranged as just described. By the passage of each wave, the vane is caused to vibrate in alternately opposite directions, following the movement and general direction of curvature of the distorted verticals. The power developed by these motions of the vane may be transmitted to the pumping or other mechanism for utilizing the same by means of connecting-rods attached to the upper portion of the vane itself, or by crank arms attached to the horizontal shaft *N*, or by any other mechanically equivalent arrangement.

When, however, as is usually the case, the water is so shallow in proportion to the length of the wave that the orbits of the particles are quite elliptical, in which case there is considerable horizontal motion at the bottom, the vane is preferably suspended from above, at a point of its length near the mean height of the center of pressure.

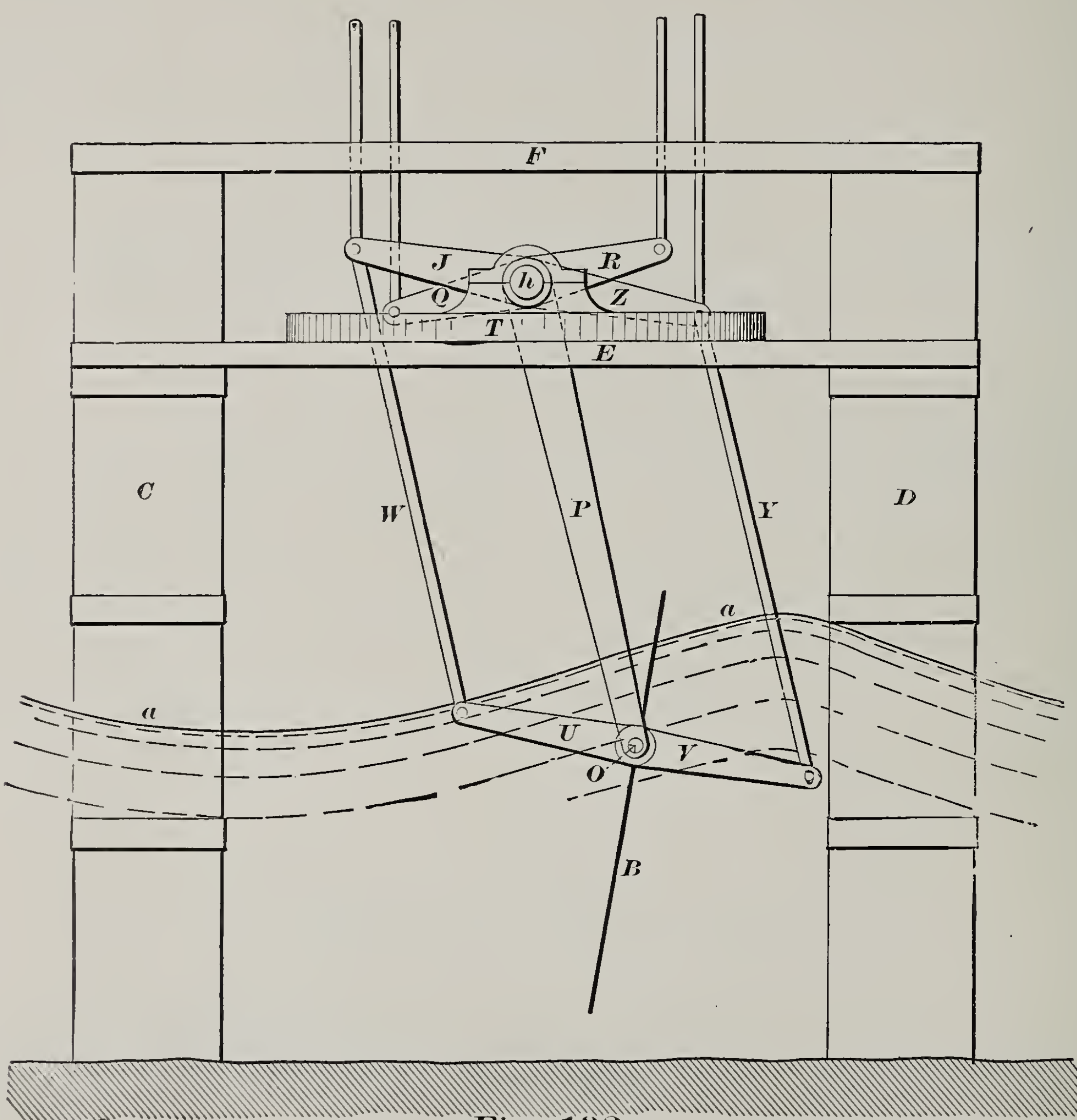


Fig. 132.

In Fig. 132, *a a a* is the wave profile, and *B* is a vane of the kind just referred to. The vane is suspended at the points *O* by crank arms *P*, at each end, these crank arms having an axis of rotation *h* at their upper ends, and the vane being free to revolve in bearings, *O*, at their lower ends. Thus, as the vane is caused to move in alternately opposite directions by the passage of a wave, that portion of the total power which is due to

the translation or displacement of the vane as a whole, causes the crank arms, *P*, to vibrate from side to side, the amplitude and energy of such vibration depending on the size of the wave. But, in addition to this motion of translation as a whole, the vane also rotates about its axis *O*, in order to adjust itself to the general direction of the distorted verticals. The cranks *U*, *V*, are therefore rigidly secured to the vane at the point about a horizontal axis to adjust itself to the general direction of the distorted verticals causes an equal rotation to be imparted to the cranks *J* and *Z*. The *total* power due to the motion of the vane is thus employed to give motion to the crank arms *P*, and to the cranks *J* and *Z*. These motions may then be transmitted to suitable pumping or other mechanism for utilizing or storing this power by any of the ordinary suitable

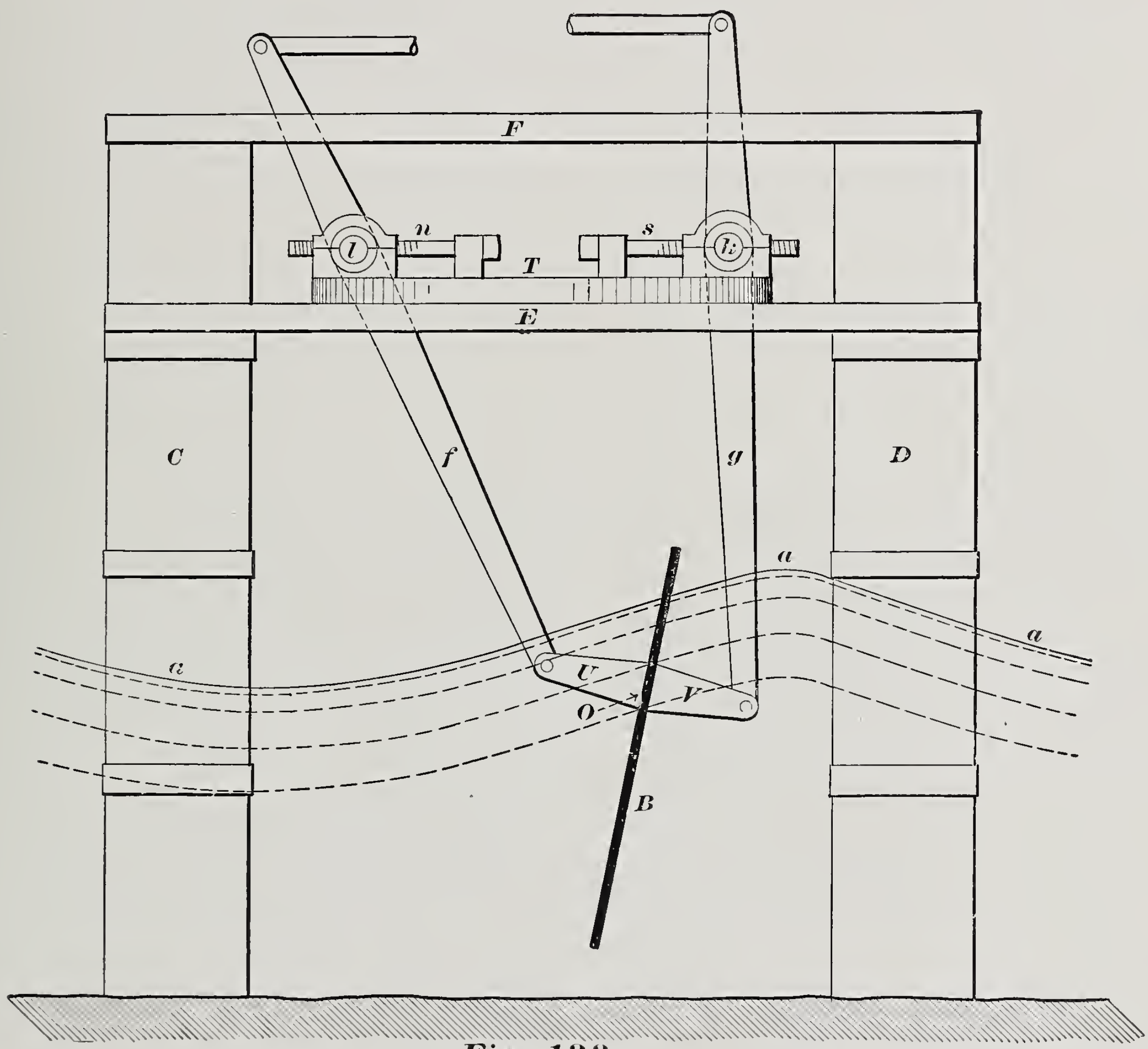


Fig. 133.

O. To the end of each of these cranks is joined a link, *W* and *Y* respectively, of the same length as the crank arm *P*, these links being jointed at their upper ends to the cranks *J* and *Z*, respectively. These cranks *J* and *Z*, are the same length as the cranks *U* and *V*, and are free to turn about the axis *h*. Thus, as the vane is caused to move in alternately opposite directions by the passage of the wave, that portion of the total power which is due to the rotation of the vane mechanical connections. Thus, in the figure the cranks *Q* and *R*, each provided with a connecting-rod, are shown rigidly secured to the crank arms *P*, and connecting-rods are joined to the cranks *U* and *V*; but any other mechanical equivalents may be substituted, if preferred.

For any given depth of water the curvature of the distorted verticals, as well as their translation or displacement as a whole, depends on the dimensions of the

wave ; and for any given wave, the curvature and the translation of such distorted verticals bear a definite proportion to each other. These two motions can be promoted or determined experimentally for a particular contour of bottom, depth of water, and size of wave ; and the vane can, by suitable mechanism, be caused to rotate about a horizontal axis while undergoing the motion of translation imparted to it by the wave, this motion of rotation being regulated to bear, at all times, the proper proportion to the motion of translation.

In Fig. 133, *a a a* is the wave profile, and *B* is a vane of the kind just referred to. To the vane are rigidly secured the crank arms *U* and *V*, each of which is supported by and pivoted to another crank, *f* and *g* respectively, the latter being supported and pivoted at the points *l* and *k*. By means of this mechanism any translation or displacement of the vane as a whole is accompanied by a proportional rotation of the same about the axis *O*, the proper ratio between these two motions, for any particular series of waves, being secured by suitably adjusting the distance between the bearings *l* and *k*, by means of the screws *n* and *s*. The power due to both translation and rotation is taken off by the cranks *f* and *g*, and transmitted by connecting-rods at their upper ends, or by any other equivalent method, to suitable pumping or other mechanism for utilizing or storing this power.

While other arrangements of mechanism may be devised to permit the vane to approximate as nearly as possible to the motion of the distorted verticals, the three arrangements just described seem the most simple and efficient of those that have suggested themselves to us ; and of these three, the one shown in Fig. 133, is of most general application, and usually to be preferred.

In order to adjust the vane *B* about a vertical axis to suit the direction of the waves, there is provided in each of these arrangements a turn-table, *T*, which, by means of suitable mechanism, is turned and adjusted to any desired position and properly secured after adjustment. The turn-table supports and carries with it the bearings, the vane, and all other necessary parts. This turn-table may be dispensed with when the contour of the coast or other influences cause a practically constant direction of the waves.

C, *D*, etc., are firmly braced structures supporting the platforms or floors *E* and *F*, the turn-table *T*, and the vane *B*. On these platforms or floors, or within the structures *C*, *D*, etc., can be placed the pumping or other mechanism for transmitting, utilizing, or storing the power derived from the waves by the vane, and the mechanism for adjusting and securing the turn-table. In practically building these structures it would probably be found best to make their lower portions closed, so as to be filled with concrete or other heavy material, while their upper portions would be open lattice-work, so as to interfere as little as possible with the movement of the wave.

The energy of the forward vibration of the distorted verticals is greater than that of their backward vibration ; and the vane will thus not vibrate equally in both directions if the same resistence is opposed to it during both vibrations. The proper and regular working of the vane can be ensured either by opposing a suitable smaller effective resistance to the motion of the vane during the backward than during the forward vibration, or by opposing to the forward vibration of the vane, in addition to the equal effective resistance opposing both vibrations, a suitable additional resistence so arranged as to yield up, during the backward vibration, the potential energy thereby stored up during the forward vibration. The former method simply requires that the amount of power derived from the vane on the forward and backward vibrations, respectively, is to be adjusted to correspond to the normal energy of the distorted verticals during these respective vibrations. The latter method is most simply carried out by the raising of a free weight or the extension or compression of a spring during the forward vibration, the potential energy of which is then allowed to assist the backward vibration. The irregularity of the vibrations which would be induced by a current can be rectified in a similar manner.

As the motion of these vanes, arranged as above proposed, conforms very closely to the natural movement of the distorted verticals, the elements of inefficiency which have been pointed out with reference to some of the previously prescribed methods are very much reduced or even altogether absent. The action of the vane is more nearly akin to that of the piston of a steam-engine, being driven forward and backward by the variations of the fluid pressure on its faces. Its weight does not affect the amount of energy, except as a slightly prejudicial factor, which should be kept as low as possible. The vane is therefore made as light and thin as considerations of strength and rigidity will permit, thus reducing the loss of efficiency due to its inertia, and at the same time reducing to the least possible amount its interference with the normal structure and movement of the wave. A notable feature about these proposed vanes is that increase of immersion is accompanied by increase of efficiency; and this is a very important point of difference between them and certain other apparatus already described. The greatest efficiency for any particular series of waves will be obtained by letting the vane extend from the surface of the wave crest to the bottom of the water; and, provided the vane is long enough to reach to the top of the highest wave crest which it is desired to utilize, the efficiency of the apparatus will not be affected by variations in the magnitude of the waves.

To accommodate themselves to variation in height of tide, most of the arrangements above discussed are raised and lowered bodily the required amount. Some of the floats are thus adjusted by simply shortening or lengthening the power ropes, which can readily be done; the floats that describe vertical arcs of circles adjust themselves by simply describing an arc which is higher up on their circle of motion; the floats describing horizontal arcs of circles and most of the vanes require their points of suspension or support to be adjustable in a vertical direction. The vanes proposed in this paper require no adjusting, being made of such length that they are long enough to reach the wave crests at high tide, while at low tide their upper ends simply project above the water.

To prevent damage to the apparatus in a heavy storm, some of the motors are located in enclosures, the gates of which may be closed in bad weather, and others are arranged to hoist out of water altogether. But as the energy of the waves is very much greater during a storm than with an ordinary swell, it hardly seems wise to throw the motors out of action at a time when they could develop the most power. We propose, therefore, to make our vanes of such length that they will reach to the top of the largest waves that can be faced with the strength of the vanes as constructed. When the size of the waves increases beyond this limit, and huge breakers come rolling in, the crests of the latter will be considerably above the upper ends of the vanes, so that the vanes will not be injured by the breaking of these crests; and as the motion of the water rapidly decreases below the surface, we consider that our proposed vanes may safely work in any weather, being entirely below the reach of the breaking crests of the waves in a heavy storm, while they project up through the wave crest in ordinary weather.

The action of successive waves is usually more or less irregular, and the action of even a perfectly regular series of waves imparts to any wave motor a variable velocity ranging from an instant of absolute rest at each end of its stroke to a maximum velocity about midway between these points of rest. As the practical utilization of any available power usually demands that such power shall be furnished at a fairly uniform rate, it becomes essential to employ some means to reduce this inherent irregularity to the smallest possible extent so far as the transmission of the power is concerned. Most of the apparatus referred to in the foregoing pages is provided with some sort of a ratchet arrangement, so arranged that a main shaft is caused to turn continuously in the same direction by each of the alternately opposite motion of the motor proper. To ensure a fair degree of uniformity of motion in the shaft, it is likewise provided with a heavy fly-wheel, and this object is still further aimed at by combining on the

same shaft the motions of a number of such motors located at a little distance from each other, in the direction of advance of the waves, or the motions of different parts of the same large float or other motor. Another and better arrangement consists in the use of a fluid accumulator, either air or water under pressure being used, the motor keeping up the pressure in the accumulator by means of pumps or air-compressors, and the main shaft being driven by an air or water engine connected with the accumulator.

But in addition to this regulation of the amount of power during consecutive revolutions of the shaft, there is required another and more important regulation. In order that the power to be derived from the waves shall have any high marketable value for most purposes, we must be able to guarantee a certain uniform supply from day to day without regard to wind or weather. Now, as the waves vary from day to day, throughout all the changes from a perfect calm to a heavy storm, and as, furthermore, the power will usually only be required in the daytime, while the wave motor may work day and night, any scheme for utilizing this power on a large scale for industrial purposes must involve a system of power storage.

There are four principal methods of storage which may be considered in this connection, viz: (1), compressed air; (2), water under pressure; (3), electric storage by means of secondary batteries; (4), water in an elevated reservoir. In the storage of power by means of compressed air the volume of air is constant, so that the pressure must vary very greatly from day to day. In addition to the great expense of storage tanks, there exists thus the strong objection that the air-compressors for pumping into the tanks and the air engines which are driven by the compressed air are required to work under very great variations of pressure. With the hydraulic accumulators the latter objection need not exist, but the large quantity of liquid required renders the tanks themselves still more expensive. The best and most perfect system of storage for many purposes is to be found in the use of secondary electric batteries, and they have the additional advantage that the power is by them furnished in a convenient form for transmission to the point where it is to be finally used. But their cost is as yet, unfortunately, so great that their employment seems entirely out of the question for our purposes. The storage of water in an elevated reservoir offers many advantages, and seems on the whole to be the best adapted for use in connection with a wave motor. When this plan is adopted it becomes unnecessary to regulate the power at the motor, as the latter may simply drive a system of pumps for delivering the water into the reservoir, the pumps always working at a practically constant pressure, and the number of such pumps in action at any particular time being regulated by the magnitude of the waves, and the consequent amount of energy in the same. The water from the reservoir may be used to drive a water-engine or water-wheel, and the power of the latter may then be further transmitted as seems best for each particular case.

The use of a water-storage reservior would have an incidental advantage in San Francisco, where the question of periodically flushing the sewers has become one of recognized importance. As this latter work does not require to be performed with absolute regularity, it could be done very cheaply by using the excess of water from such storage reservior, at such times as might prove most convenient.

The size of the storage reservoir depends on the amount of power to be continuously supplied, and on the extremes of variation in the power of the waves from day to day. In default of positive knowledge on the latter point, we may assume such an amount of variation as seems to us proper; any error in our assumption, as revealed by practical experience, will of course modify the amount of power that can be depended upon continuously.

As an illustration, let us assume that the reservoir is so located that the average level of the water in the same will be 340 feet above the water-wheel or other engine that it is intended to employ. This corresponds to a theoretical head of water of 150 lbs. per

square inch $= 21,600$ lbs. per square foot. Practically we can only count on 90 per cent. of this head, or 19,440 lbs. per square foot. Assuming a perfect efficiency for the water-wheel, the reservoir must discharge $\frac{33000}{19440} = 1.697$ cubic feet per minute per horse-power. Supposing a water-wheel to be used which can be depended on for an efficiency of 80 per cent., the quantity of water to be discharged is thus $\frac{1.6975}{.80} = 2.122$ cubic feet per minute per horse-power. Assuming further, that the power is required for 10 hours each day, the discharge must be $2.122 + 60 + 10 = 1273.2$ cubic feet per horse-power per day of 10 hours. The next most important assumption is the variation in the supply of water pumped into the reservoir by the motor. To be what seems on the safe side, let us assume that the reservoir must contain sufficient water to supply the power at the assumed rate for a period of 10 days, without in that time receiving any water from the pumps of the motor. This would require a storage capacity of 12,732 cubic feet per horse-power. If we were supplying 100 horse-power this would require 1,273,200 cubic feet, which could be stored in a reservoir 20 feet high and 252 feet square, or 30 feet high and 205 feet square; similarly for 1000 horse-power there would be required a reservoir 30 feet high and 651 feet square, or 40 feet high and 564 feet square.

In any actual installation, the power of the water-wheels would be transmitted to the points at which it was to be finally used by such means as might be most economical and convenient, taking into account both the amount of power and the distance to which it is to be transmitted. In the case of this city, it would be found best to convert the power at once into electricity by means of dynamos driven by the water-wheels, transmitting the same by overhead wires to a central station in the city, whence it could be distributed to individual consumers in the usual manner.

In conclusion, it may be interesting to note that of the 32 patents which have been granted in this country for the improvements in wave motors, just one-half have been granted to residents of California. This is probably largely due to the high price of coal in this State, which naturally causes men to look favorably on any scheme that seems likely to reduce the cost of power; while another and important reason is to be found in the fact that the ocean waves as they reach this shore are usually much more regular in size from day to day than on the Atlantic coast, thus helping to reduce the commercial difficulties of the problem. The circumstances are thus, on the whole, considerably more favorable to the success of a wave motor on the Pacific than on the Atlantic coast, as a less degree of efficiency in such wave motor would be required here than there to enable it to successfully compete against coal and the steam-engine.

STEAM DISTRIBUTION IN SINGLE-ACTING COMPOUND ENGINES.*

By F. M. Rites.

THE mechanical performance of the single-acting engine has become well known, but the structural features are usually considered to the exclusion of the peculiar method of steam distribution which has been introduced in its compound type. Moreover, the treatment which this new method has received has been too superficial and disconnected to be acceptable as an analysis. This paper will therefore consider the engine as an economic study only, the steam distribution being entirely independent of single-action or other mechanical features, and will serve incidentally to satisfy a very natural curiosity regarding the remarkably uniform efficiency under extreme variations of conditions.

It is necessary to note briefly the character of previous work, to understand properly the nature of the departure made in this new type of compound. Broadly stated, all compound engines, with this single exception, may be considered under two heads: those having an intermediate receiver between the cylinders, each with a complete valve, or system of valves, interposed between it and the receiver; and those (known as the Woolf) having no such receiver, but so designed that a port shall periodically act as a passage between the cylinders.

All the energy of inventing engineers since the design of the first compound has been expended in the development of these two forms. The patent records are perhaps the best indication of the amount of thought given to the subject; and the almost unending claims, based on the arrangement of cylinders either in tandem or side by side, with cranks in line or at an angle, oscillating or otherwise, and with valves from one to eight in number, are but variations upon the fundamental principles which distinguish one type from another. Very often a designer has felt justified in securing capital to promote an unimportant improvement or develop some ingenious though valueless mechanism. In other cases some established concern has found it necessary to build a line of compounds, without the ability to do them justice or in the least understanding the laws governing the efficiency of such steam distribution. That many of these forms can scarcely be considered improvements and that others are positive failures, is but natural and to be expected; but the great majority give much better results than the same class of simple engines, assuming both under good conditions for the comparison.

Of the two types, the receiver is better known, although it is necessarily the more complicated. The general choice may be explained by the fact that each cylinder may be treated by the designer as an independent simple engine, with its own complete system of valves, and with the receiver acting as a secondary boiler.

While the Woolf type permits a simpler construction, the difficulties attending a proper steam distribution, especially under varying conditions, have prevented a general adoption. In fact, its occurrence is so rare as to be practically unknown.

To better appreciate the difference in the action of the steam in the two types, the following ideal comparative diagrams are given, with the distinguishing features in each noted (Figs. 149 and 150).

With the aid of these cards, let us trace the objections to each system as a preliminary to the reasoning which led to the correction of the faults in the new type.

In the Woolf engine the resultant enormous compression in the high-pressure cylinder with small clearance and

* Paper read before American Society of Mechanical Engineers.

early low-pressure cut-off, or the great loss through clearance with a moderate compression, and the inability of any construction to maintain its efficiency under even ordinary changes of conditions, has effectually prevented the development of this type.

It has been perfectly possible to design a special form of Woolf compound which should be highly economical; but the design invariably possessed no elasticity in its application, and rapidly lost in its efficiency with a change of load or pressure.

The receiver type, however, is much more flexible in this respect, and will allow more variation in construction and conditions of operation, without unduly increasing the rate of steam consumption, until the range of conditions becomes considerably greater. In all engines of this class, however, free expansion into the receiver, as illustrated in the ideal card, means proportional loss in economy. The receiver is really a clearance space, causing a loss greater or less according to its capacity and to the rise in pressure during the exhaust of the high-pressure cylinder. The argument that the energy lost in this expansion is absorbed by the remaining steam in the receiver is in accordance with the conservation of energy, but it is wasted energy, as it is not afterward returned to the engine. Under constant conditions, the same amount of steam which leaves the high-pressure cylinder must enter the low-pressure cylinder; and if the initial pressure of the latter be less than the terminal of the former, there is a difference of potential energy in these two conditions that no subsequent manipulation can recover.

Another source of loss in the receiver is the change in pressure and temperature to which it is subjected.

There can be no doubt that the laws relating to condensation and retarded re-evaporation hold true with the receiver, as with the cylinders. An increase in the size of the receiver increases the area of condensation and radiation, so that, all other things being equal, the increasing consumption of steam must keep pace with the capacity of the receiver.

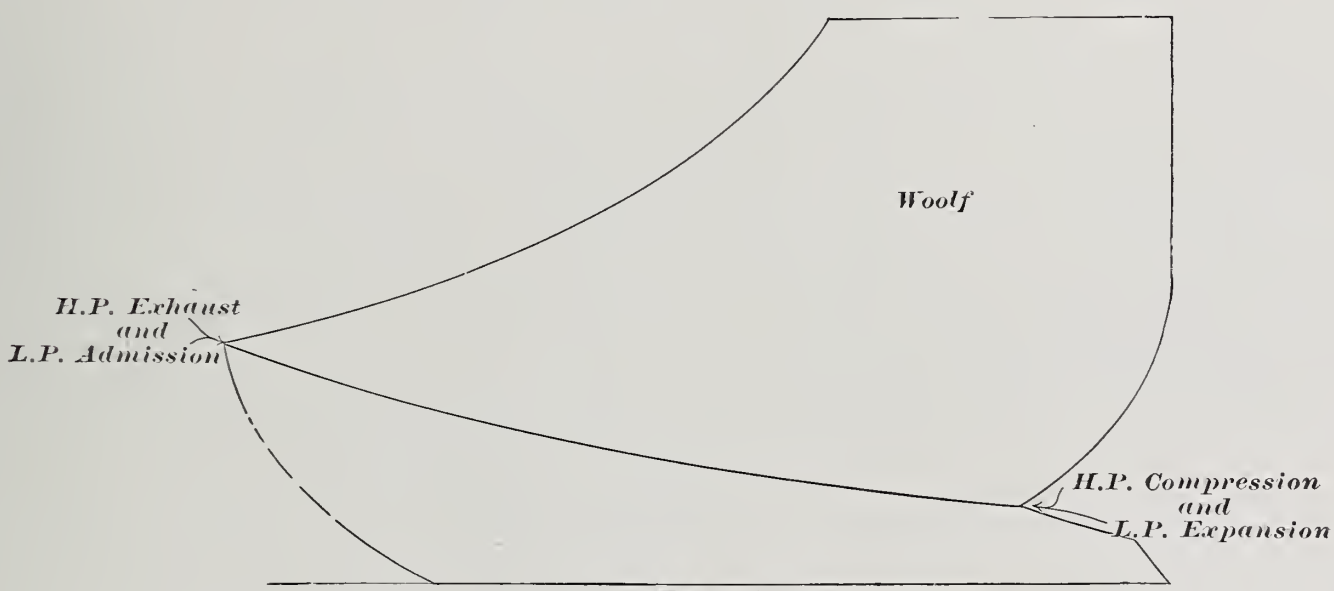


Fig. 149.

Recent practice seems to be in favor of the smaller receiver, so that the steam distribution more nearly approximates that of the Woolf type; but the margin of conditions under which the engine can be operated economically is reduced exactly in proportion as the high economy incident to the Woolf engine is approached in this manner.

For a considerable over-load or under-load, the engine must be redesigned with respect to its steam distribution, or operated at a much lower efficiency, as is the law in a greater degree with the Woolf engine.

Inasmuch as it is the exceptional case where an engine is exactly suited to its work, the average commercial perform-

ance is far from what can be obtained under test conditions.

The evil is more marked with light than heavy loads ; and in work demanding extreme variations of power the high-pressure cylinder is frequently forced to supply all the power and in addition drag along with it the low-pressure piston, whose cylinder indicates negative work.

The indicator card (Fig. 151) will illustrate this action perfectly, and show that the proper division of temperature between the cylinders was possible only with the load for which the engine was intended.

As the whole range of temperature is covered in the high-pressure cylinder, the economy of the engine approaches that of a simple engine ; but the net result is a considerable loss over what could be realized from the single cylinder alone, on account of the additional friction and enormous internal negative work of the low-pressure cylinder.

It has been but a short time since this question demanded consideration. Heretofore, compound engines have been built for particular kinds of work where load and steam pressure were maintained nearly uniform ; while any considerable increase in the original plant was quickly followed by the installation of an engine of suitable power.

Since the rapid development of electrical industries, a demand has originated for an engine of high and comparatively constant economy under the widely different conditions incident to this service ; and it was particularly true in the case of electric railways, where the average horse-power might correspond with the engine's rating, yet the actual working load would range far above or below this amount the greater part of the time. So great is this commercial loss with high-class compounds under such conditions, that it is still an open question with engineers whether simple engines in a subdivided form and maintained at a uniform load, are not more economical than centralized power, in the form of a compound, subjected to such varying loads.

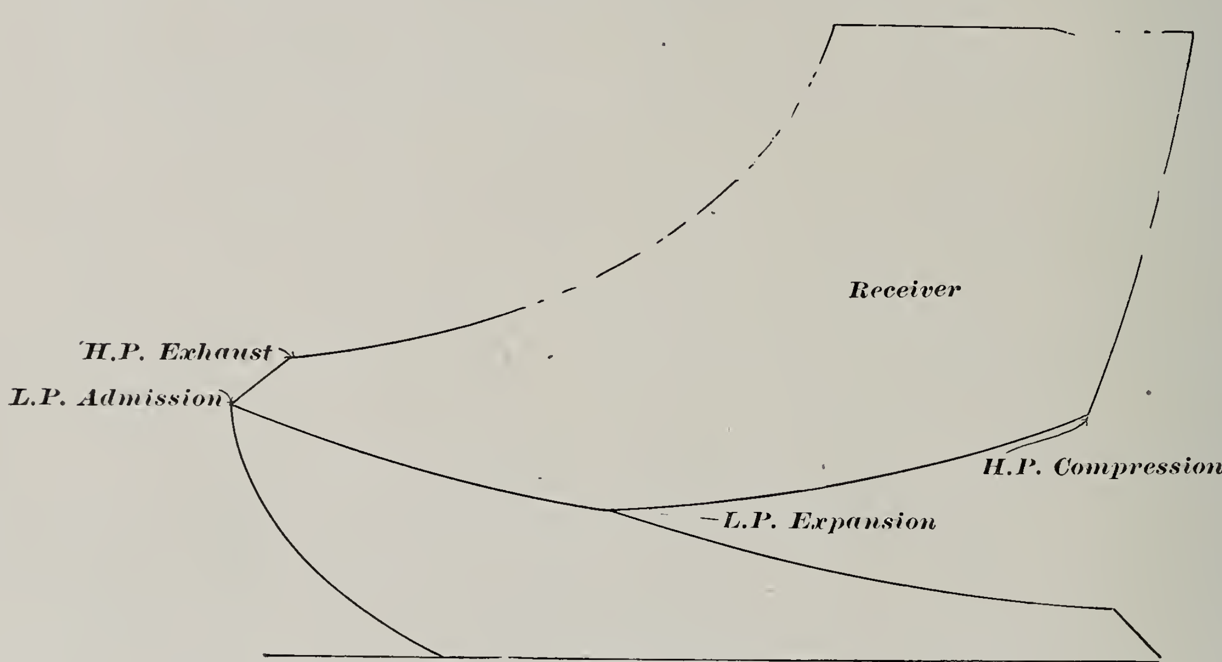


Fig. 150.

The objections which have been considered are general in their nature, and applicable to all compounds in degree according to the type they represent. They are wholly independent of the speed or any other distinguishing feature that characterizes a particular style of engine.

From the limitations thus described, it will appear that the problem to be solved was reduced to the following :

Given an extreme range of conditions as to load or steam pressure, either or both, to fluctuate together or apart, violently or with easy gradations, to construct an engine whose economical performance should be as good as though the engine were specially de-

signed for a momentary condition—the adjustment to be complete and automatic.

Technically, this may be reduced to read : Design an engine compounded, whose individual cylinders shall be subjected to a constant range of temperature, under constant limiting pressures, with different loads, and whose governor shall automatically readjust the division of the total range of temperature with different pressures at either extreme of the cycle, and at the same time regulate the speed.

This sounds worse than the first presentation, but it may readily be explained graphically by the diagram above (Fig. 152). A represents total range of temperature. B represents range of temperature in high-pressure cylinder. C represents range of temperature in low-pressure cylinder.

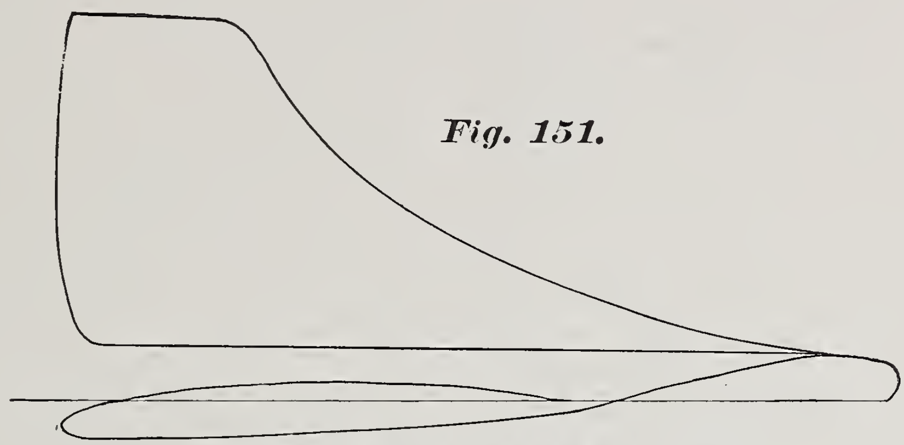
The total range of temperature due to fall of pressure and represented by the distance (A) must at all times, whatever the condition, be automatically divided between the cylinders on the intermediate line (D) in the predetermined proportions represented by the distances (B) and (C), which are nearly inversely proportional to the surfaces subjected to the partial ranges of temperature.

The element of time, however, introduces a factor having no connection with the speed of the engine, but with a direct reference to the relative rapidity of the fall and recovery of temperature in each cylinder.

More properly, the line (D) should be located in accordance with the expression

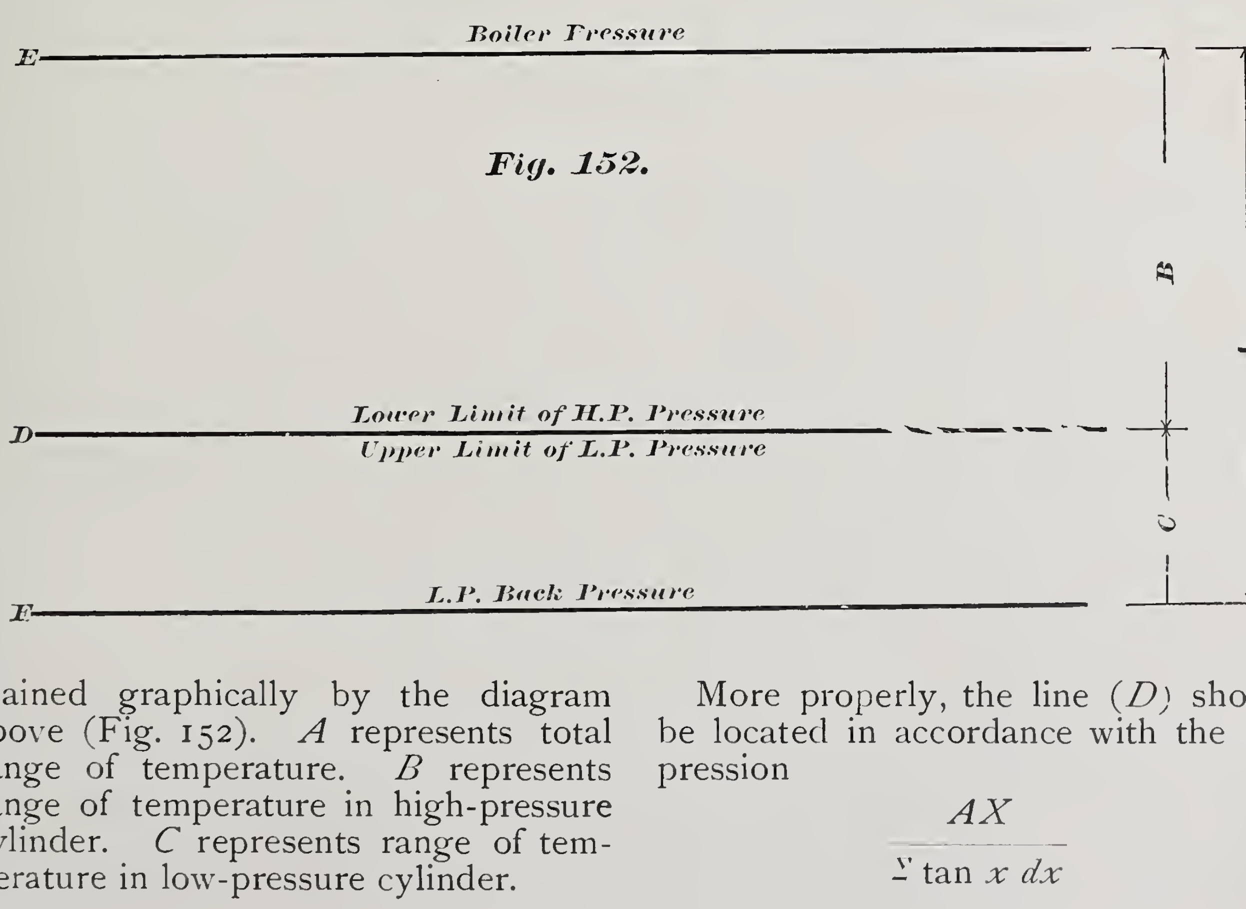
$$\frac{AX}{\Sigma \tan x \, dx}$$

Fig. 151.



Receiver Compound with Light Load

Fig. 152.



where a is practically constant, and includes in its composition the ratio of the exposed surfaces; while Σ is the sign of summation and $\frac{\Sigma \tan x \, dx}{x}$ represents the rapidity of recovery of the change of temperature.

With our modern high boiler-pressures, neglect of the proper correction for the difference in the rate of change of temperature becomes quite noticeable in its effect on the economy of the engine. Thus corrected, however, the line (D) falls very slightly in the early cut-offs and rises in the later ones, and except for this slight amount its position must be unchangeable with the load; but with a change of pressure and consequent temperature at either extreme, it must as quickly move to a new position, still maintaining its proportional distances (B) and (C) of the whole distance (A). For instance, in case of a failure of vacuum, the line will rise, or with a fall of boiler-pressure it will likewise fall, always, however, maintaining the same relative position between the lines (E) and (F) under constant load.

It may be readily believed that the fulfillment of this self-imposed contract was not an easy matter, so that the successive steps in their order of develop- may be interesting.

At first expansion curves alone were considered and discussed, with, however, no idea of the development of a distinct type of engine. In fact, quite contrary to the usual plan, the form of the engine was not determined until after the steam distribution was developed. The objections to the older forms were recognized; but for a long time no means were discovered to correct them. Either seemed to require such a complicated system of valve-gear to obtain a proper distribution of steam, that it became very doubtful if a commercially better article than already existed could be worked out. The Woolf engine seemed unsuitable, for reasons already explained, although long consideration was given it. In the receiver engine, the little line which marks the fall of pressure between the cylinders was a stumbling-block that obstinately intruded itself.

After several months of investigation, the discovery was made of the peculiar valve of a receiver of predetermined volume which should act as a clearance chamber for compression in the high-pressure cylinder. This can better be understood by reference to the fragmentary indicator card (Fig. 153).

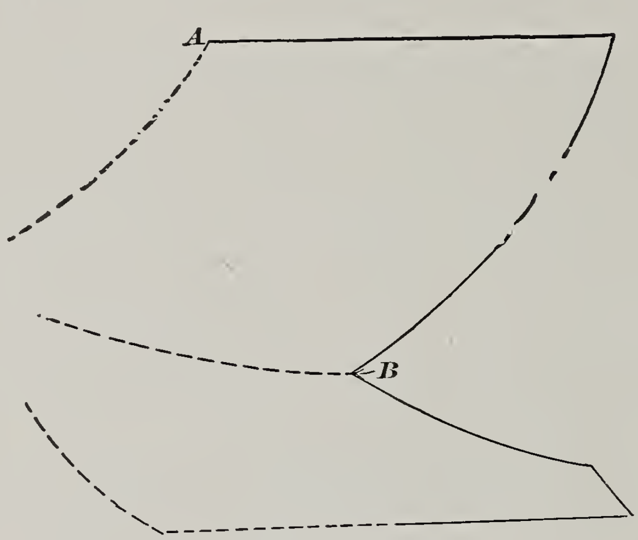


Fig. 153.

It may be stated in general that an engine may be designed that will cut off at any convenient point (A) in the high-pressure cylinder, and through process of expansion reach the point (B), the cut-off in the low-pressure cylinder, from which point the steam can be compressed to boiler pressure in the high-pressure cylinder, and expanded to a proper terminal in the low-pressure. We have so many unknown quantities, that we are at liberty to vary any one or several at will, without altering the results. For instance, if the clearance

which allows a proper compression in the high-pressure cylinder be changed, we are at liberty to change the point of cut-off in the low-pressure cylinder so that the same degree of compression is maintained. If, however, it be stipulated that the cut-off in each cylinder shall be equal, then the high-pressure clearance can no longer be altered, but must be a certain definite quantity.

If, again, the distribution be effected by a single valve, driven by a shaft governor, the cut-off in each cylinder must be equally variable, and the point (B) will follow a path according to the law of its production, and dependent on the proportionate parts of the engine.

this path might be made to coincide with the hyperbola of the compression curve.

A variation in the cut-off of the high-pressure cylinder varies the point (B) to or from the atmospheric line ; while a variation of the low-pressure cut-off changes its position in a direction parallel to this line. A simultaneous variation of both cut-offs makes the resultant movement of the point upon which so much depends, and which is determined by the clearance of the high-pressure cylinder.

With an independent valve for each cylinder, it would be easy with any convenient clearance to so vary the cut-off in the low-pressure cylinder, that the variation of pressure at this point, due to varying cut-offs in the high-pressure cylinder, should cause the point (B) to fall on any high-pressure compression curve that should be determined on ;

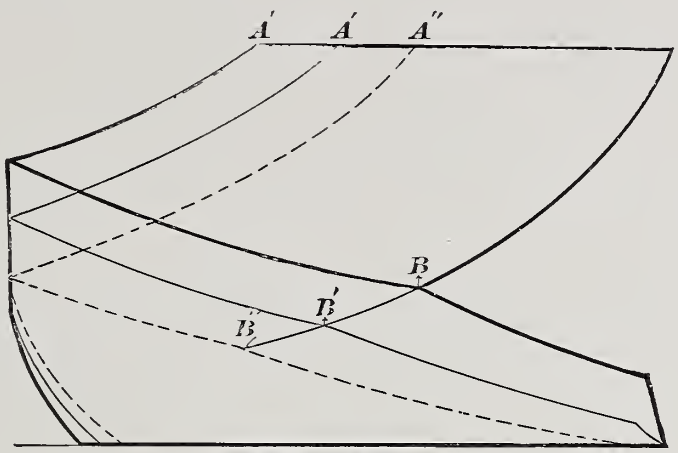


Fig. 154.

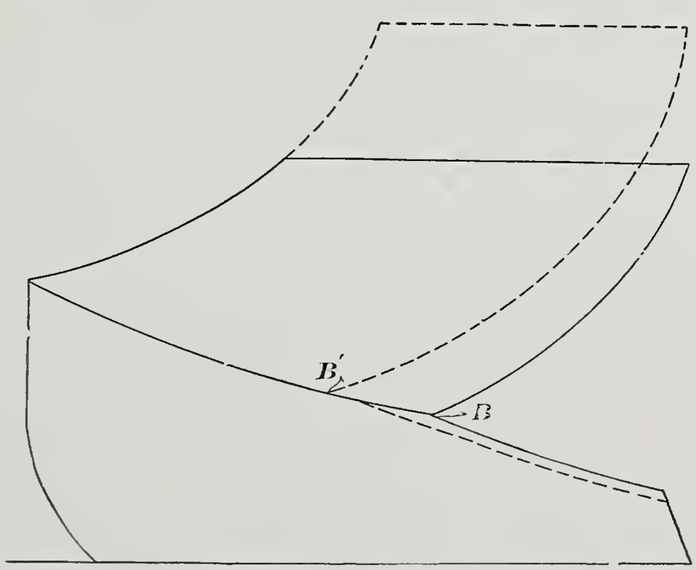


Fig. 155.

The particular discovery that proved so valuable was, that under these last conditions, the point (B) (Fig. 154) followed the path practically of a hyperbola, and that with a proportional clearance equal to the ratio of the cylinders,

but with a single eccentric valve-gear these points of cut-off must always be equal and similarly variable, so that the discovery was really essential to the simplicity that was attained.

It seems a lucky chance, although it is really part of the law which controls the movement of this point, that, as the pressure changes and the high-pressure compression varies, the point (*B*) leaves the path to which it has so closely adhered, and adopts a new one—still a hyperbola—which cuts the steam line at the same point of admission (Fig. 155).

So far, all considerations have been with the seemingly eccentric behavior of the point (*B*), and the reduction of its locus to a law which has been turned to important practical use, while the position of the cut-off gives a positive value to the clearance chamber, varying but slightly (Fig. 156).

The average cut-off of one-half declares that the amount should be such a percentage of the high-pressure cylinder as the high-pressure cylinder is of the low-pressure cylinder; and at cut-offs on each side of this point to the limiting practical positions the clearance volume departs so little from this amount that the error can be corrected by the very slight shifting of the valve through a coincident varying angularity of the eccentric-rod. That is, under shorter cut-offs, a little greater clearance is required, and on longer cut-offs a trifle less is necessary; and to balance this error the angularity of the eccentric-rod

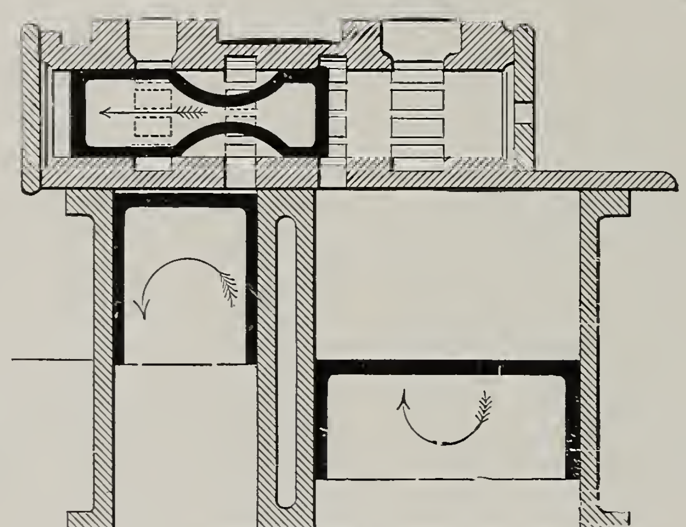


Fig. 156.

results have been obtained with a form of valve which has but one lip between the two cylinders.

In the course of the investigations, the proper amount of high-pressure clearance to suit the various points of cut-off was graphically determined, and a rather curious result obtained at the limiting full stroke and zero cut-offs. With steam carried full stroke in both cylinders, the high-pressure clearance must obviously be zero, to compress to boiler-pressure in the high-pressure cylinder; while with zero cut-offs in both cylinders the clearance may be anything to accomplish this result. These unsatisfactory and indeterminate volumes were, however, caused by the error of considering conditions that are impossible in practice. Any intermediate can be made to introduce a counteracting error, by which the high-pressure cut-off changes more rapidly than that of the low-pressure. In practice, the error measured in pounds of steam consumed is so slight as to be unnoticeable; and, in fact, for other reasons which shall appear, these varying dependent cut-offs are caused to depart from one another in exactly the opposite direction.

Although the compression in the high-pressure clearance space to initial pressure is theoretically correct and advisable, yet certain narrow departures from this degree may be allowed without materially altering the economy, if by means of this a much greater gain can be made at some other point in the steam distribution.

If the distribution of steam were entirely dependent on the truth of the point (*B*) to the path in which we have constrained it to move, then the line (*D*) (Fig. 152) would in reality fall slightly with shorter cut-offs and rise again with the longer ones. Fortunately we have still the low-pressure compression with which to make a fit finish to the usually tiresome work of correction.

Under the influence of a single-valve variable cut-off, the low-pressure compression rises from a constant pressure, but with a period varying almost as rapidly as the cut-off.

The benefit in this case of such a peculiarity is in early exhaust closure with the lighter loads to prevent undue radiation to the condenser, and to raise the temperature of the cylinder so that there will be no surface condensation when the steam port reopens.

In the later cut-offs the water of condensation is re-evaporated to a great extent before the point (*B*) is reached, and a considerable portion of the original steam is recovered for compression in the high-pressure cylinder; but, in the earlier cut-offs, re-evaporation does not begin until the high-pressure cylinder is shut off from the low-pressure, so that it is important there shall be little or no secondary initial condensation.

The amount of heat radiated during exhaust is dependent somewhat on the speed of the engine, and nearly proportional to the time the exhaust port is uncovered; so that an early compression, with a short cut-off, is valuable in reducing the total radiation to the condenser, thereby making the percentage of loss more nearly constant, as well as reheating the cylinder to prevent initial condensation.

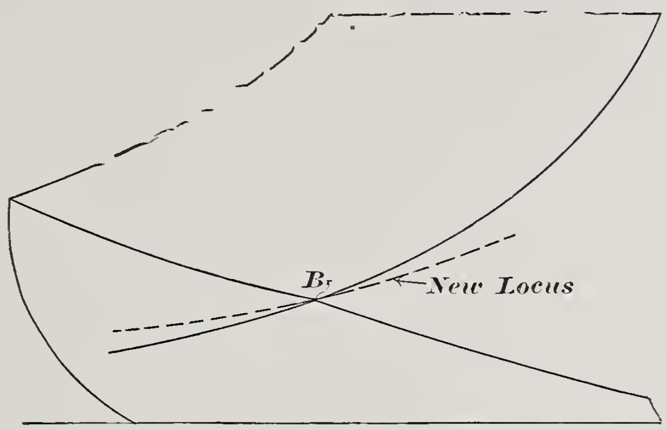


Fig. 157.

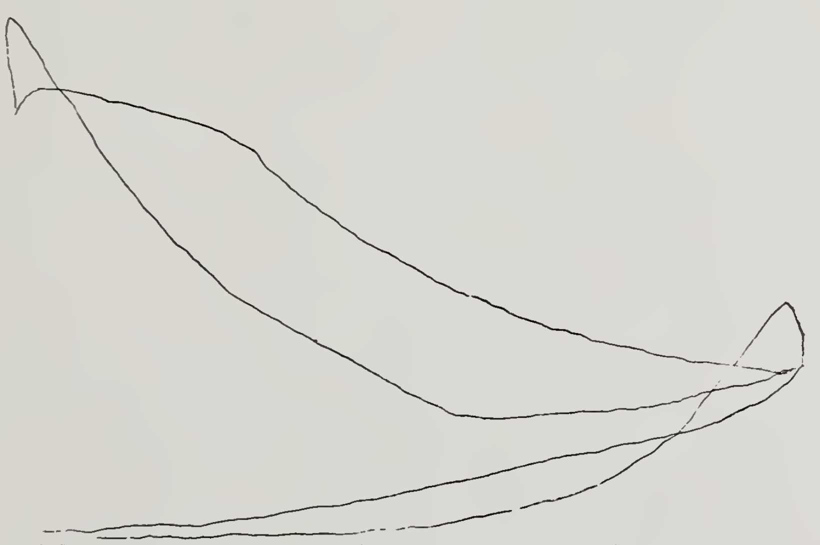


Fig. 158.

To the very natural question as to the reason for neglecting the radiation in the longer cut-offs, the answer is that the gain in power sinks the percentage of loss from this cause to such a small amount that the engine really effects a net gain by ignoring that factor.

Moreover, the variable low-pressure compression acts as a corrective influence over the point (*B*), which, if left to follow the course subject to the equally variable cut-offs in the two cylinders alone, would too rapidly lower the line (*D*) (Fig. 152).

The variable low-pressure compression would, however, overdo the work we have indicated, were the angularity of eccentric-rod not interposed as an anti-corrective measure, and the progression of the low-pressure compression retarded, while the point (*B*), thrown slightly from the path to which we have assigned it, varies the high-pressure compression a little on each side of the constant curve of its true path (Fig. 157).

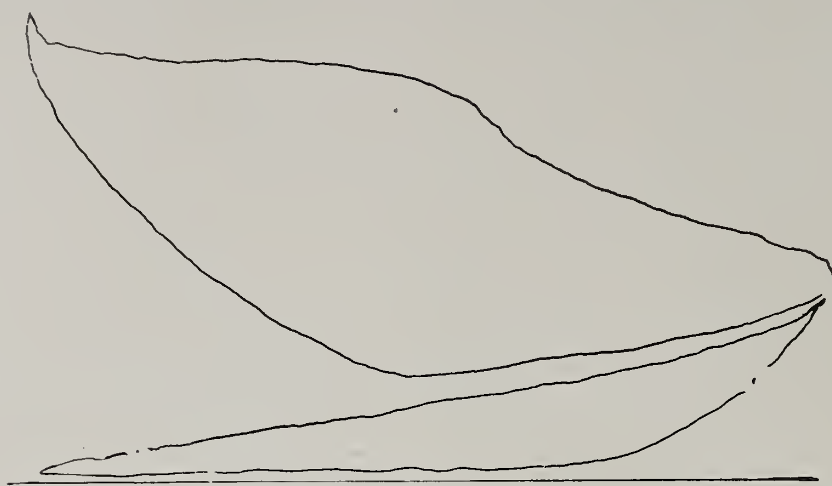


Fig. 159.

The diagrams (Figs. 158, 159, 160), reproduced from actual cards, and representing light, medium, and full loads, respectively, illustrate the practically constant division of temperature between the cylinders, and are a graphic proof of the successful application of the new method.

The practical results in fuel consumption are represented by the tabulated water rates under different conditions, both condensing and non-condensing.

WATER RATES, BY TEST, UNDER VARYING LOADS.

Horse-power.	210	170	140	115	100	80	50
Non-condensing.........	22 6	21.9	22.2	22.2	22.4	24.6	28.8
Condensing................	18.4	18.1	18.2	18.2	18.3	18.3	20.4

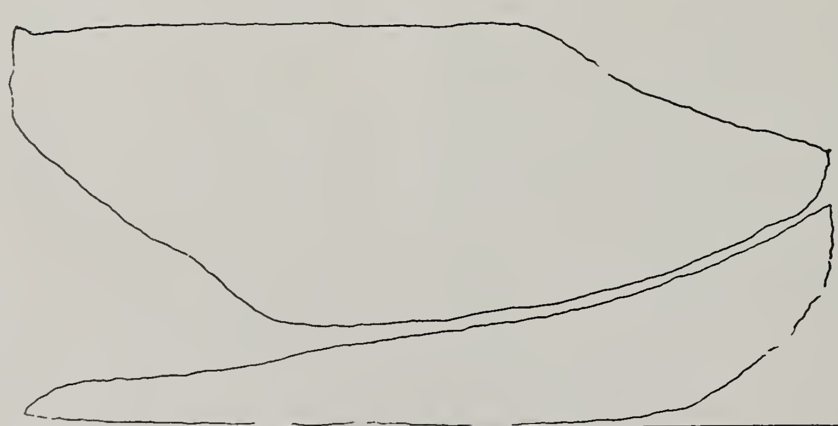


Fig. 160.

It would be insufficient to dismiss with so brief a mention the subject of radiation to the condenser, and the influence of the variable low-pressure compression as a partial correction for this

loss and a factor in the development of the constant economy under varying conditions that has been accomplished.

A properly variable low-pressure compression may be regarded only secondary in importance to the practically constant high-pressure compression ; and as this design has undoubtedly originated the principle of overcoming by a proper compression the otherwise great waste of a large high-pressure clearance chamber, so it is also believed to be the first to practically acknowledge and control the heat of radiation during low-pressure exhaust by a properly variable low-pressure compression.

After the detailed explanations it will be interesting to note, as an evidence of the remarkable flexibility of the practical engine, that the valve adjustment may be set so far from true that the shape of the indicator cards are considerably altered without materially affecting the economy of the engine.

The explanation is that the line (*D*) does not depart from its position unless the valve error be excessive, because the error introduced by such readjustment on one cylinder is in a measure corrected by a balancing error on the other cylinder. It must be understood that the whole economical result of the engine is directly dependent on the path of the point (*B*) ; and that, in the finished locus of the point, every part of the engine has an influence, greater or less. As a type the engine must be considered as a union of the two older ones, partaking of the nature of each, yet with the objections to either eliminated and the good qualities of both retained. The receiver is so disguised as to be scarcely recognized, and, as a clearance cavity to the high-pressure cylinder, absorbs all of the compression instead of only a part. On the other hand, the single dividing lip of the valve reduces its functions to resemble those of the Woolf type.

Ordinary possible derangements have little or no influence in changing the division of temperature and the consequent economy of the engine ; yet a radical change in dimensions, such as the shape of the valve which contains the clearance space or in the proportion of the cylinders, would necessitate an entire new design, in which every other part should reconform to the single departure.

A NEW PORTER-HAMILTON ENGINE.

THE engine illustrated herewith was designed and built for the Youngstown Electric Light Company by William Tod & Co., of Youngstown, O.

As will be seen from the engraving, it is of the tandem compound type and is non-condensing. The bed and general details are of the well-known Porter-Hamilton pattern as usually built by Messrs. Tod & Co. Piston-valves are used on both cylinders, the low-pressure valve having a fixed travel and cut-off, and the high-pressure being actuated by a shaft governor. This governor, of which we furnish an illustration, is designed and patented by Mr. C. Seymour Dutton, of the above firm, and is intended to protect the position of the governing mechanism from the disturbing effects of valve friction and inertia of reciprocating portions of the valve-gear. This action will be easily understood from inspection of the cut without further description. The high-pressure cylinder of this engine is 12 inches diameter, the low-pressure 21 inches, and the stroke of both 21 inches. It is run at 230 revolutions per minute and under a load of about 250 horse-power.

Commenting on its smoothness of operation, the builders insist that there are only two secrets in the construction of good running engines and that they are : plenty of metal and good workmanship. It will be noticed, however, that they have not neglected directness and gracefulness of design, nor the proper provision for correct steam distribution.

GEORGE I. ALDEN.

PROF. GEORGE I. ALDEN, whose portrait appears on another page of this issue, has earned for himself a place among those teachers in our technical schools who are doing so much to educate the engineers of the future. He graduated from the Lawrence Scientific School in 1868, and shortly afterward secured a position as teacher of theoretical and applied mechanics in the Worcester Polytechnic Institute, Worcester, Mass., with which institution he has ever since been connected. Prof. Alden now fills the chair of professor of Mechanical Engineering and has carried on a great amount of valuable original investigation in that field. In 1880 he was elected a member of the American Society of Mechanical Engineers, to which body he has contributed some important papers, among which are "Technical Training at the Worcester Free Institute," "Formulæ and Tables for Calculating the Effect of the Reciprocating Parts of High-speed Engines," "A New Belt-testing Machine," and "An Automatic Absorption Dynamometer."

Absorption dynamometers are usually represented by the Prony brake in some of its various forms. Since the work done by the machine is here absorbed in friction, the mechanical energy delivered by the machine is transformed into an equivalent amount of heat. The heat so given off heats the surfaces of the brake and of the wheel, and tends to change the coefficient of friction, which in turn produces a jerky motion of the brake-arm. Means must be provided for lubrication, and for removing as much as possible of the heat generated. For low pressures little inconvenience is experienced, but for high pressures it becomes a serious matter.

The automatic absortion dynamometer, invented by Prof Alden, is designed to secure a perfectly steady and uniform load for any motor, and to accurately measure that load. The load is produced by water-pressures against copper plates, these plates being thus pressed against the sides of a disc revolving with the shaft. The copper plates are secured to an outer cast-iron casing, there being a water-tight compartment between the cast-iron and the copper plates. The casing has a lever arm rigidly connected to it, so that the turning effect can be balanced and measured the same as in the ordinary Prony brake. The disc runs in a bath of oil. The pressure of water is automatically regulated by a valve, which is partially closed if the brake-arm rises above the horizontal, and is partially opened if it falls below ; this with a constant head gives exceedingly close regulation. The current of water keeps the oil at a constant temperature, and the friction produced is the friction of the oil. Examination of the copper plates on dynamometers used for a considerable time indicates that there is practically no wear upon the plates. The dynamometer is adapted in different sizes to all ranges of power, from a fraction of a horse-power up to one or two hundred horse-power, per 100 revolutions per minute.

It can be used with equal facility in making accurate tests of electric motors, steam-engines, water-wheels, or steam turbines.

Reflections and Observations.

THEORY is apt to prove a very expensive article unless diluted with a large proportion of good common-sense and practical knowledge. The proprietor of one of the new hotels on upper Broadway recently employed as the house electrician a young graduate of a second-class technical school. The dynamos for the lighting plant were placed in the basement with a high-speed automatic cut-off engine on each side. The line of motion of the piston-rods being perpendicular to the dynamos, the young man thought the electrical machinery would seriously affect the action of the engines. He, therefore, proceeded to make the proper correction for this attractive influence by changing the position of the valves on the head end of the cylinders, and, as a further preventive, he placed a glass partition between each engine and the dynamos. Shortly afterward, the builder of the engines, who was an excellent engineer, came to see how they worked and, on beholding the wonderful state of affairs, he exclaimed, "That young man will be a professor some day."

A FEW years ago the editor of *Harper's Magazine*, in his "facetious" page, printed the following item as a news note:

"It is rumored that the standard of admission to Cornell University is to be raised to five feet ten inches next term. The examining board will admit no one to the Freshman class who weighs less than one hundred and fifty or more than two hundred pounds, and who cannot row over the measured mile in the time specified in the college laws. Last year, owing to the laxity of the examiners, two young men were admitted to the Freshman class, one of whom had studied algebra, the other of whom had actually read one book of Cæsar. It is needless to say that neither of these men can row, and the scandal which their admission has caused has led to a demand on the part of the trustees for greater thoroughness in examining candidates in future. W. L. A."

TWO American engineers who were traveling abroad last summer, one of whom was not familiar with the French language, strolled into a garden in Paris which had a famous old well. One of them said, "Let us look down into the old well to discover truth, which the proverb assures us is at the bottom." As they stood, a French abbé approached the well, and courteously saluting them, asked what they were looking for, displaying, as he spoke, beautiful teeth. An evasive answer was given by the gentleman who understood and could speak with him.

His companion said, in English, "How I would like to know what dentifrice he uses!"

The priest asked what was the remark,

and he simply and truthfully translated it.

He answered, "These are new teeth; I am just from my dentist."

"Then I must tell you, sir," he replied, "that we were looking down the well in search for truth at its bottom; but we have found it much nearer—in your mouth."

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I WAS riding from Patterson to New York city a few days ago when a pleasant-faced young German got aboard at Passaic along with a lot of commuters. The man was of a talkative disposition, presumably a barber, and in a short time he began the conversation.

"Do you live in Passaic?" I asked, after a time.

"Yes, I works in New York and go in and out on a communication ticket."

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THE true nature of a vacuum is a very hard matter for some minds to understand, being unable to decide whether it is some intangible substance with marvelous properties, or whether it is allied to the magical elements that Pandora carries in her wonderful box. Some time ago, I was indicating the engines of a steamer used to transport hides, when I asked the engineer some questions regarding the operation of his machinery.

"Everything works nicely except when the boilers are not steaming properly in certain kinds of weather," he said.

"How can you tell when the weather is impairing the action of your boilers?" I asked.

"Because, then the vacuum smells very bad," was his reply.

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A VERY peculiar incident was lately brought to my notice which illustrated in a striking manner how impulse and automatism may usurp the place of intellect and reason. A machinist in a certain shop had taken a belt punch from the office, and after he had finished using it, started to return it. As he was moving through the office, he chanced to pass a clerk who was bending over his books. The machinist playfully said, "Tickets, please," and as the clerk's ear chanced to be close to the machinist's hand, the latter at once punched a hole into the ear in the most approved fashion. The action proved as great a surprise to the doer as to the unfortunate victim, who is now considering the advisability of having the other ear punched in the same manner "so they will match."

THE OBSERVER.

PROF. WM. C. UNWIN, F R.S. COLEMAN SELLERS, E.D.
PROF. E. MASCART. SIR WILLIAM THOMPSON, L.L.D., F.R.S. COUNT TURRETTINI.

THE INTERNATIONAL NIAGARA FALLS COMMISSION.

CASSIER'S MAGAZINE.

VOL. II. JUNE, 1892. No. 8.

THE NIAGARA FALLS TUNNEL.

By Charles H. Werner.

THE first method of utilizing the water-power at Niagara on a large scale was by the old hydraulic canal, which commenced on the shore of the river above the falls, and extended about three-quarters of a mile to its discharging-place on the high bank of the gorge below the falls. During the fifteen years of its operation a number of large manufacturing establishments have located along its course. This old surface canal diverted a very small fraction of the force flowing over the falls, yet while so many small water-powers existed in the New England States and other sections of the country, the unlimited power of Niagara was permitted to remain practically untouched. But water-power in America is gradually diminishing as the country becomes more thickly settled. It has become necessary, at many places, to supplement the water-power with steam in order to run machinery during the twenty-four hours. To-day nearly every available horse-power existing in the old Niagara hydraulic canal is utilized. This demand for power amid such favorable circumstances, together with the recent development of electrical science, long ago convinced engineers and manufacturers that the time had come for a larger utilization of the enormous water-power of Niagara Falls.

In 1886 a charter was granted to the "Niagara River Hydraulic Power and Sewer Company, of Niagara Falls, N. Y.," whose plan was carry the fall of Niagara river from above the falls, back to a district along the shores of the upper Niagara river, by means of a tunnel about one and one-half miles long. According to the original plans of Mr. Thos. Evershed, the tunnel constituted a main tail-race, to be used jointly by all the mill-sites. The present Niagara Falls Power Company is the successor of the one above named.

For the construction of this great work, the Cataract Construction Company has been organized, which has secured the services of the following prominent engineers : Albert H. Porter, engineer ; Coleman Sellers, John Bogart, and Theodore Turrettini, consulting engineers ; George B. Burbank, resident engineer ; and Professor George Forbes consulting electrical engineer.

Mr. Clemens Herschel, who has recently completed the construction of the works of the East Jersey Water Company, is the hydraulic engineer for the Cataract Construction Company. Mr. Herschel graduated from the Lawrence Scientific School of Harvard College in 1860 and completed his technical education in the scientific school at Carlsruhe, Germany. He spent three years in this school, and on his return to the United States immediately began the practice of his profession, which he continued for fifteen years at Boston. During the last two years of his stay in Boston he was at work on the main drainage works there. Thence he went

INTERIOR OF TUNNEL DURING CONSTRUCTION.

to Holyoke, Mass., as hydraulic engineer of the Holyoke Water Power Company, where he remained for ten years when he connected himself with

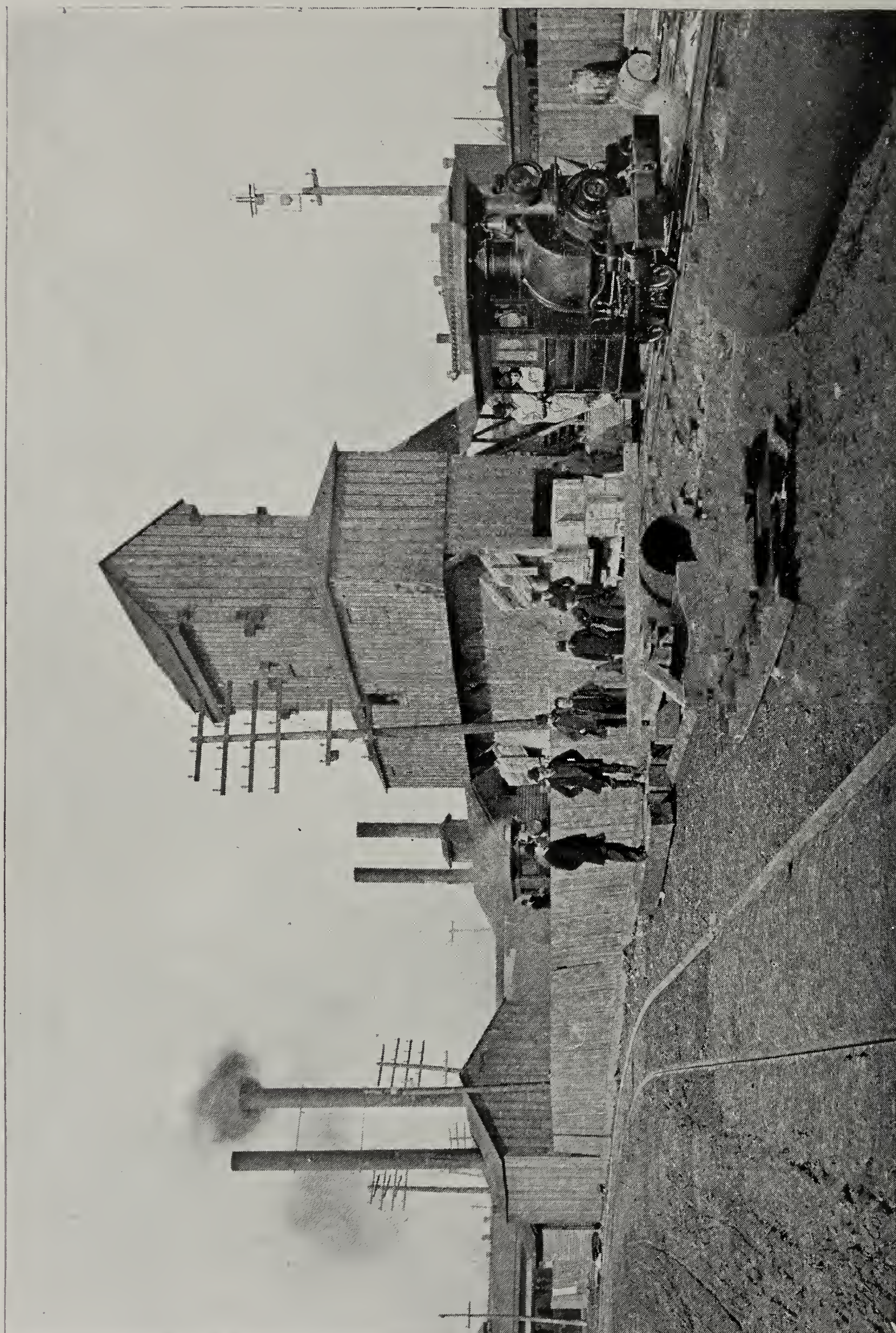
FROM PROSPECT POINT.

the East Jersey Water Company. Mr. Herschel is a member and ex-director of the American Society of Civil Engineers, and is a member of the British Institution of Civil Engineers.

The central feature of this work is the great tunnel, 6700 feet long, which will form the tail-race. Several illustrations printed herewith, show the progress of work on this tunnel, which, starting from the river at just above the water level, below the falls, and running under the city of Niagara, will have its upper end beneath a large tract of land that the company has purchased adjacent to the river bank above the city. The tunnel has somewhat of a horseshoe shape, being 19 feet wide by 21 feet high inside of the brickwork, with which it is to be lined throughout, and will have a cross-sectional area of 386 square feet for its entire length. The base of the tunnel at its discharge-point, below the falls, is 205 feet below the sill of the head-gate, at the entrance of the main canal from the river above the falls. This represents the total fall, of which 140 feet will be available, the difference being taken up by the allowance for clearance from the wheel-pits, incline of the lateral tunnels leading therefrom to the main discharge tunnel, and the incline of the latter, which is made at a grade of 36 feet to the mile. The tunnel is lined on the invert and sides for a distance of 200 feet, back from the discharge-point, with closely fitted cast-iron plates, there being a heavy cast-iron frame at the mouth, and the tunnel is furthermore lined throughout with four courses, a total of 16 inches of brick. The work of rock excavation, the average height of which was 26 feet, was effected on three different benches, the top bench, 9 feet high to the top of the arch, being always extended ahead of the second bench, 8 feet high, the workmen in the latter bench being covered by a flooring, over which the material excavated from the top bench was conveyed backward on small dump-cars. The excavation on the bottom bench, which measured 9 feet vertically to the bottom of the invert, was not commenced until the work on the other two benches had been nearly completed. After the work was well under way, the rock-cutting was effected at a rapid rate, 338 feet of tunnel, averaging 14 yards to the running foot, having been excavated in 26½ days.

FROM THE CANADIAN SIDE.

Three shafts were put down in the construction of the tunnel. At the discharge-point below the falls, where the

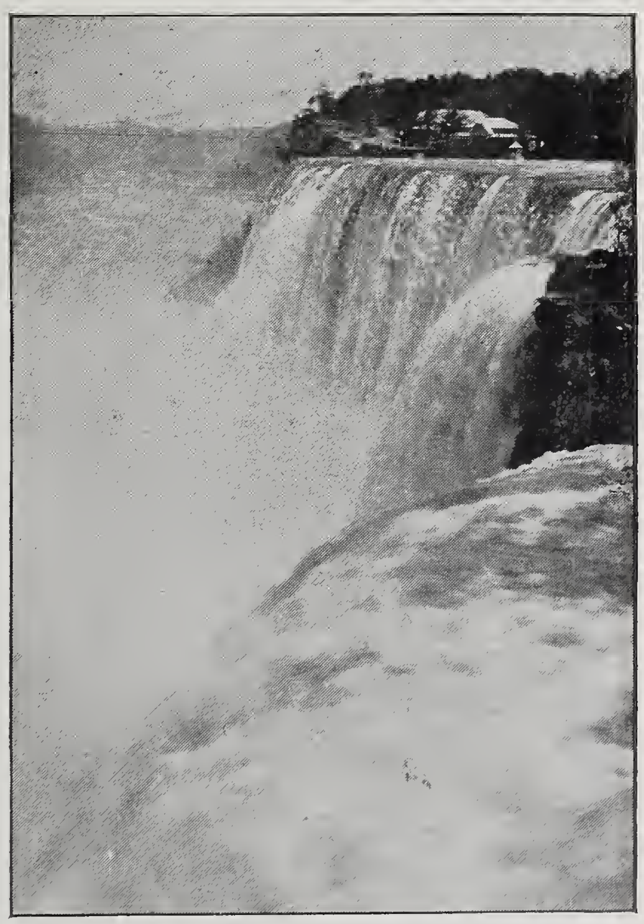


SHAFT NO. 2.

top of the river bank is 214 feet above the level of the water, the "Zero" shaft was sunk. This shaft is 10 by 12 feet in size and passes along the face

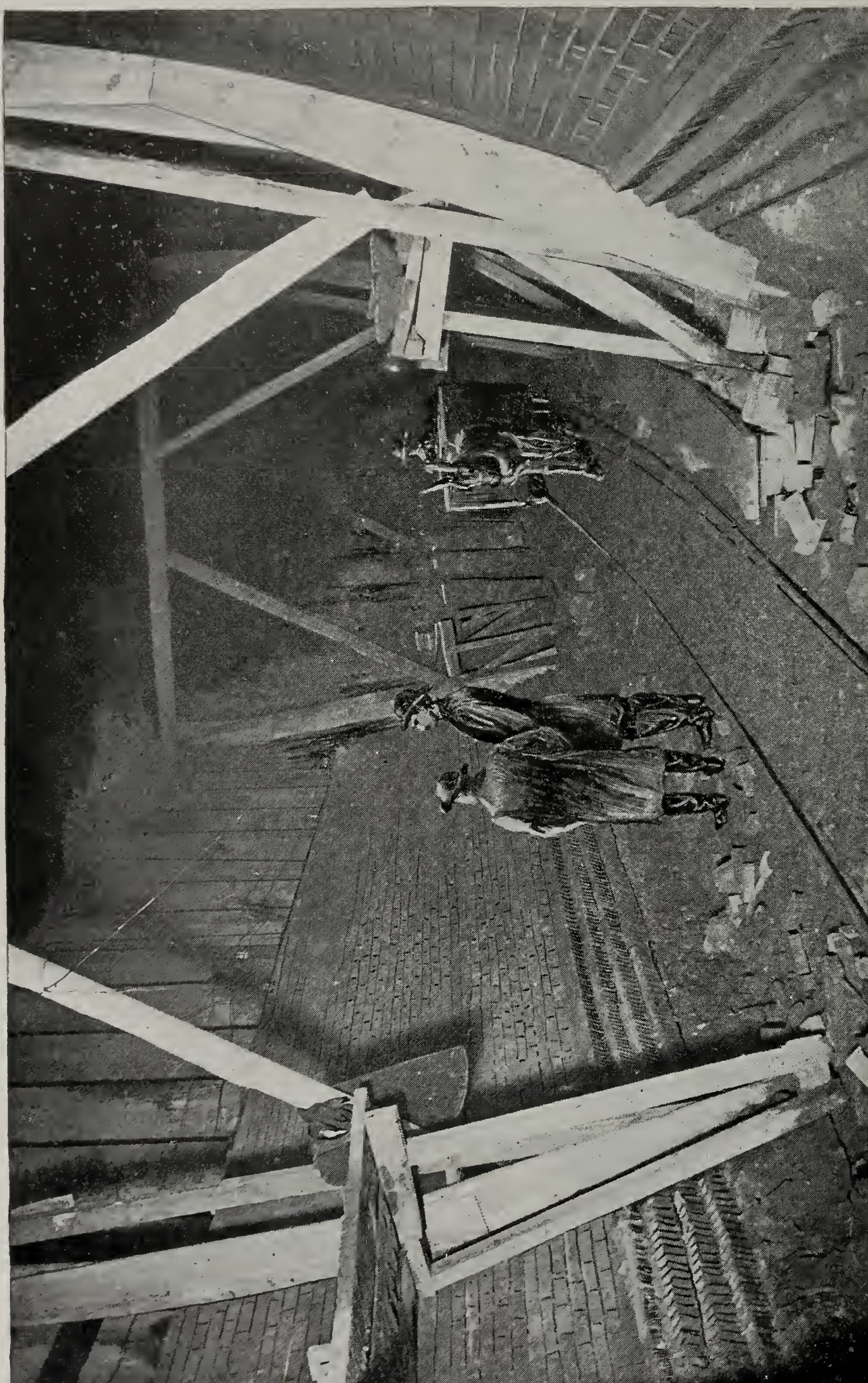
THE WHIRLPOOL.

of the cliff until it strikes a ledge of rock which it pierces to the soffit of the tunnel arch. Shaft No. 1, 2650 feet from the portal, was sunk 206 feet and is 10 by 20 feet in size, while shaft No. 2, of the same size and 196 feet deep, is 5200 feet from the discharge-point. In putting down the shafts, 140 feet of the work at the top was through hard bastard limestone, which overlays the Niagara slate or Utica shale, met with for the remaining distance, and through which the main tunnel itself was mostly made; its base, as it reached away from the river, being in Queenstown limestone. The company has made thorough investigations as to the best kind of turbine to use and the method of setting the wheel, as well as the most effective means of transmitting the power obtained. There is room for only a limited number of mills or factories close to the end of the tunnel, and the total area that could be developed by surface canals and extension of the tail-race tunnel is not great enough to absorb 100,000 horse-power, so that in order to get the area of land required to use so much power it is necessary to transmit the power to a considerable distance from the falls. Mr. Edward D. Adams, the president of the Cataract Construction Company, and Dr. Coleman Sellers went to Europe to examine systems employed abroad for transmitting power. Together they visited Paris, where electricity and compressed air are used for power; Geneva, where water under pressure is distributed for power; and the great workshops where turbines, pumps, compressors, and electrical machinery are made. After consulting with leading engineers, it was proposed to place the collected information in the hands of an international commission, which would consider plans that might be submitted to it, and might award prizes to those schemes that seemed worthy of such honor. The commission was organized under the presidency of the eminent electrician Sir William Thomson, and Professor W. C. Unwin, so well known as a hydraulic engineer and a writer of engineering text-books, was induced to act as secretary of the commission. The other members of the commission were Professor E. Mascart, member de l'Institut, Paris, and directeur du Bureau Central Météorologique; Colonel Theodore Turrettini, president de la Ville de



FROM TERRAPIN ROCK.

Genèva, directeur des Travaux d'Utilization des Forces Motrices du Rhone à Geneva, and directeur de la Societé Gènevoise d'Instruments de Physique;



TUNNEL SHOWING INCOMPLETE BRICK WORK.

and Dr. Coleman Sellers, member Inst. C. E., etc., Professor of Engineering Practice Stevens Institute of Technology and Professor of Mechanics, Franklin Institute.

The competitors for the prizes offered

AT THE TUNNELS MOUTH.

by the construction company sent in many voluminous reports accompanied by numerous drawings. One prize of £500 was divided between two firms of Geneva, Switzerland, Messrs. Faesch & Piccard and Messrs. Cuenod Sautter & Co., who acted in association. Prizes of £200 each were awarded as follows: Messrs. Hillairet & Bouvier, Paris; M. Victor Popp, of Paris, and Professor Reidler, of Berlin; Messrs. Vigreux & Levy, Paris; The Pelton Water-Wheel Company, San Francisco; and The Norwalk Iron Works Company, of Norwalk, Conn. The two firms receiving the largest prize offered two complete projects of similar character for the utilization and electrical distribution of 125,-

PORTAL OF THE TUNNEL.

000 horse-power. The general features of both projects are the adoption of Gerrard or impulse turbines, with complete admission and back vanes, permitting the use of suction-pipes, so that the fall below the turbines is not wasted; a unit of power of 2500 horse for each turbine; and in the electrical distribution, the adoption of continuous currents at constant potential.

The Oerlikon Company has put forward a project for transferring power from the falls to the city of Buffalo by the use of a three-phase alternating current. The power to be transmitted amounts to 5000 horse-power, which will be given off by three or four horizontal turbines. The 4-polar dynamos, with drum armatures, will be directly connected with the shafts of the turbines,

THE ROCK OF AGES.

WORK OF CONSTRUCTION ON OPEN CANAL.

which will make 250 revolutions per minute.

The Pelton Water-Wheel Company proposes to use wheels 14½ feet in diameter, in pairs, running 60 revolutions per minute; each wheel being supplied by five nozzles with hydraulically-worked valves. For air-compressing a 21½-foot wheel would be used, making 40 revolutions and having eight nozzles. The cost of water-wheels, exclusive of excavation and erection, and also exclusive of pumps, compressors, air, few advocating transmission by wire rope. This wire-rope transmission, once the pride of Swiss engineers, is now giving way to electricity, and the transmission of the future will be disputed between electricity and compressed air." No plan has, however, been finally adopted by the company. A portion of the power will be sold to mills controlling their own wheels and delivering water into the tunnel, but at the central station the designs are, primarily, for the utilization of 20,000 horse-power.

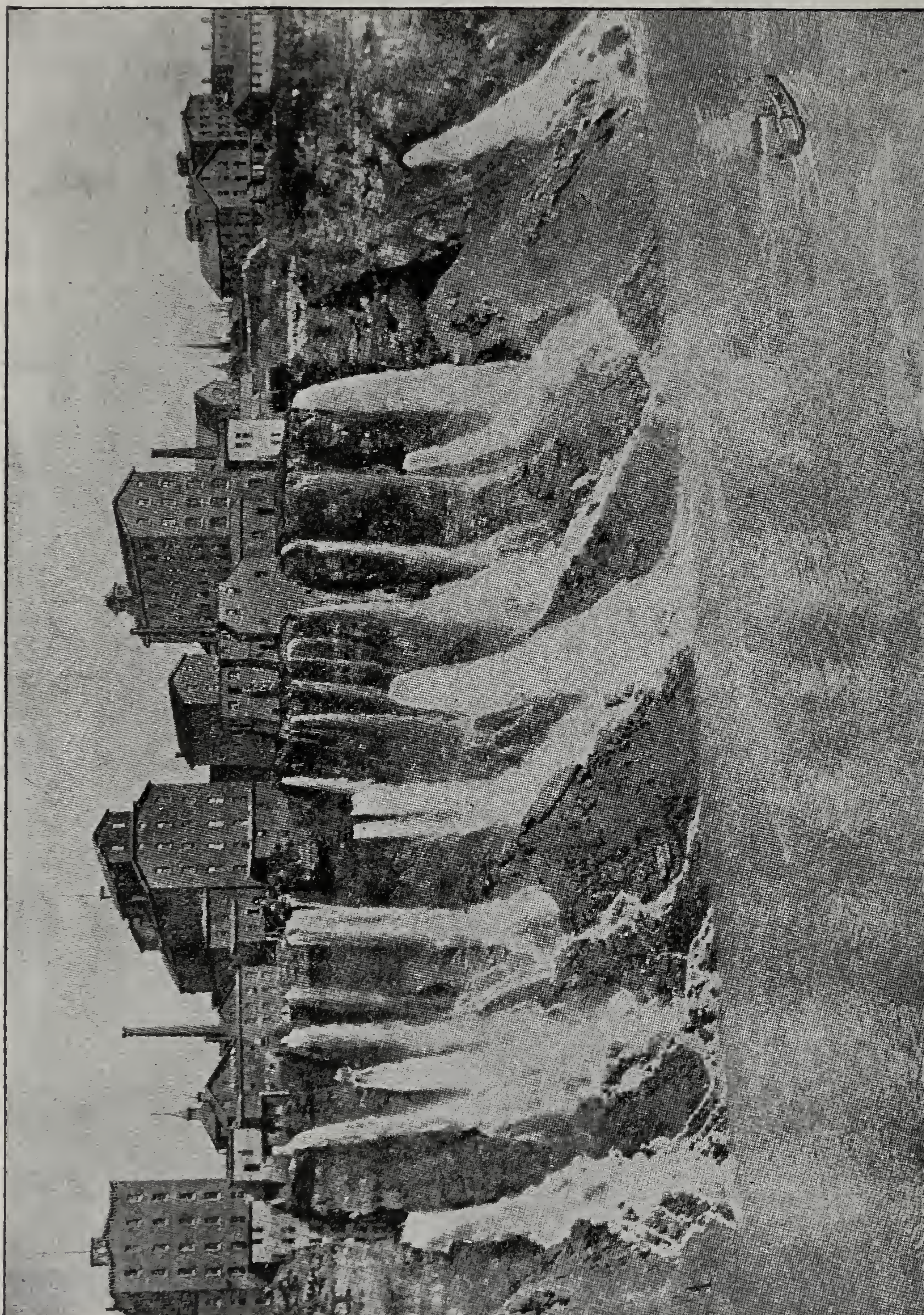
RAPIDS BELOW THE FALLS.

and dynamos, is given at $3.90 per horse-power. The wheels are to be guaranteed at 80 per cent. efficiency, although the makers expect 85 per cent.

In a lecture recently delivered at the Stevens Institute, Dr. Coleman Sellers said that regarding the transmission of power by far the greatest number of the competitors submitted plans "purely theoretical, of transmission by electricity, or plans varying greatly in all particulars, but grounded on actual practice of transmitting by compressed

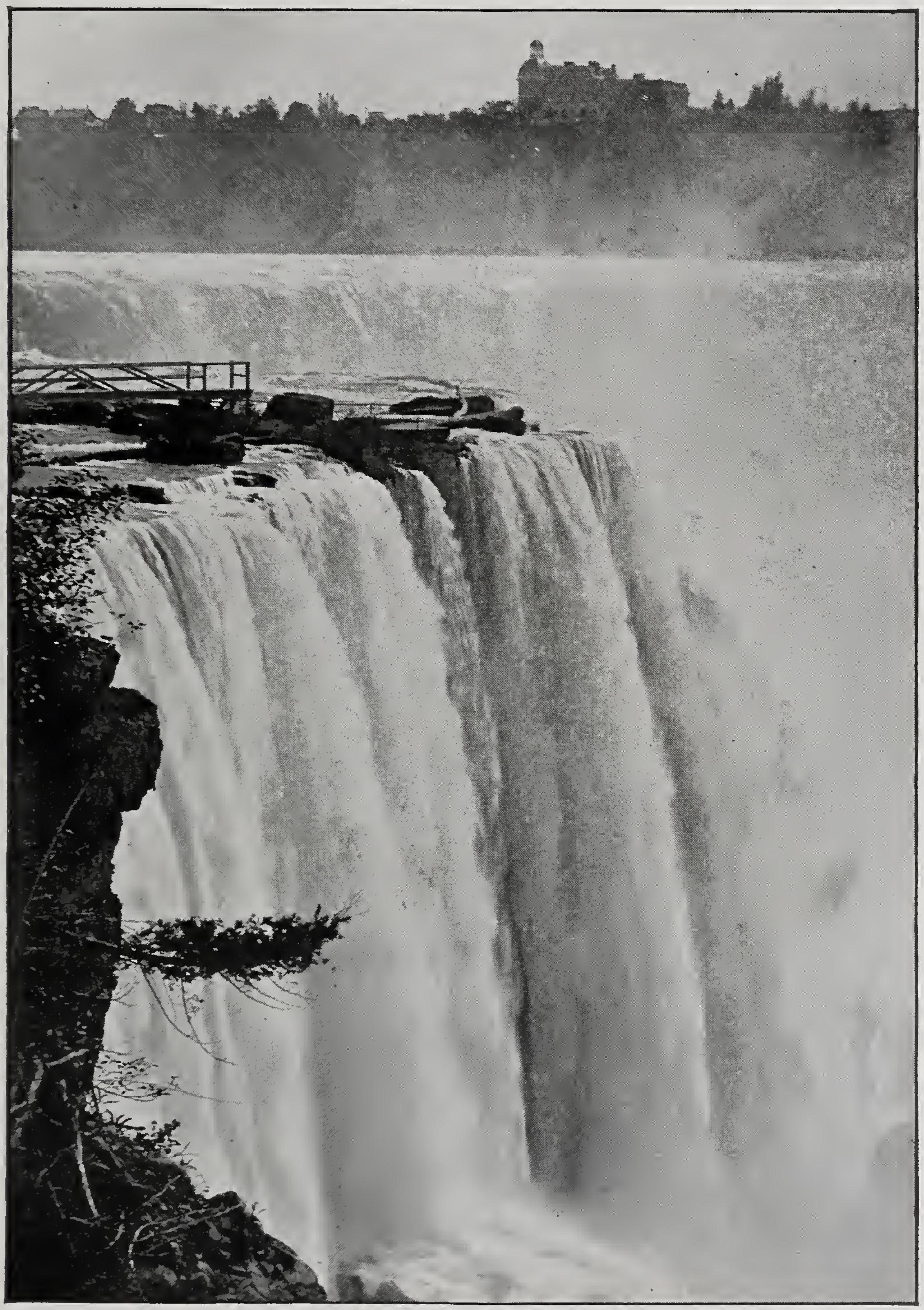
The tunnel has a capacity of 100,000 horse-power. Careful provision has been made for the gradual growth of the whole plant, without interference with the portions already in use.

The general plan of the main supply canal includes a lower reach 200 feet wide, extending 1200 feet inwardly from the river, thence parallel to the river in an up-stream direction for nearly 5000 feet, where an upper reach 500 feet wide connects this end with the river. On the lower reach of this canal, the only part



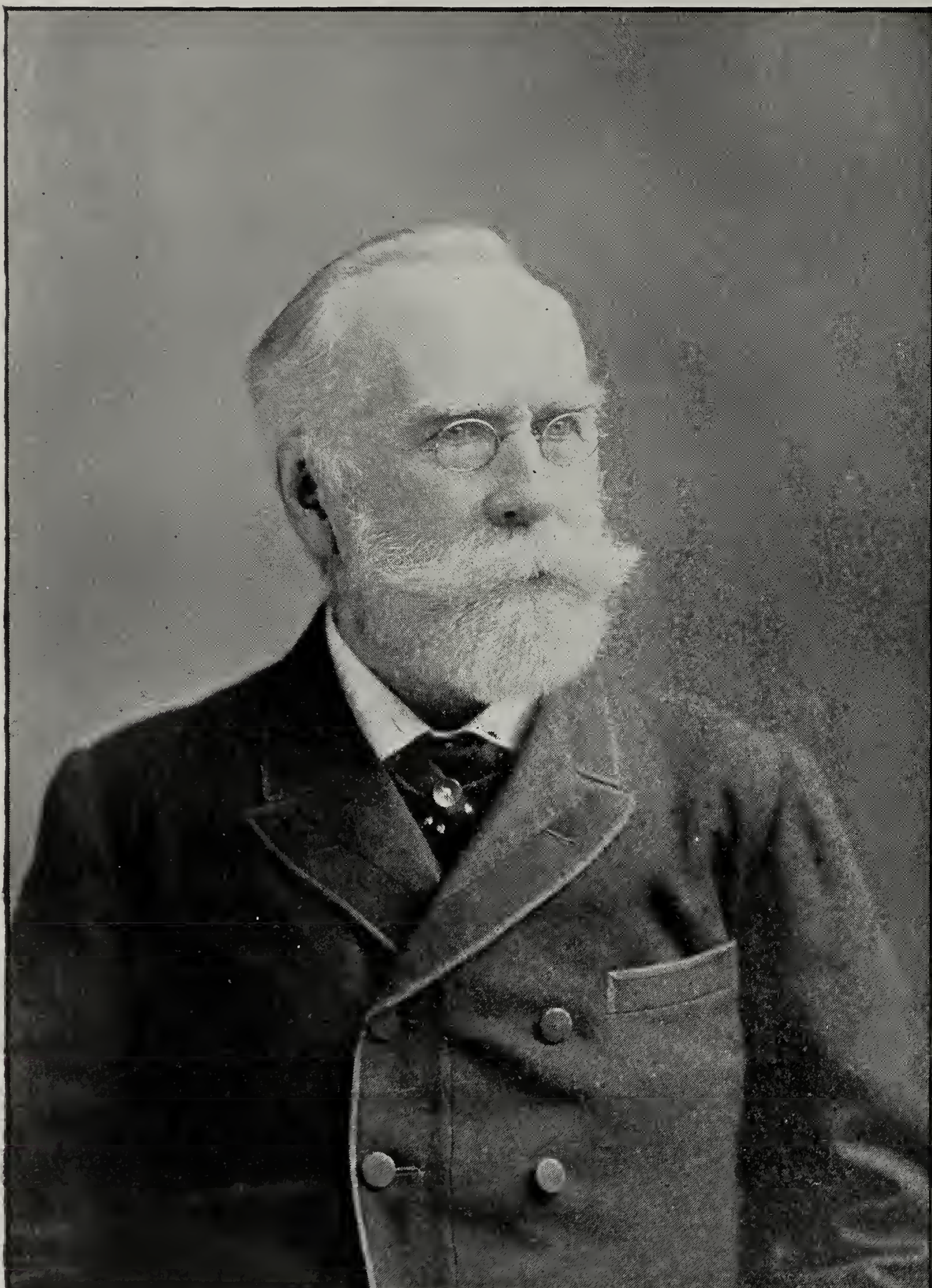
THE PRESENT MILLING DISTRICT.

thus far in process of construction, are to be located works intended to be run without intermission, and it is here where the extensive establishment of the Niagara Falls Paper Company will be located. Here, also, is located the site for the water-works of the future city. The plan of these works contemplates taking the pure waters of the upper Niagara river outside of Grass Island and pumping them to a suitable stand-pipe.



HORSESHOE FALLS FROM GOAT ISLAND.

Three years ago the Niagara Falls Power Company sent agents into the district it proposed to occupy and very quietly secured options on hundreds of acres of land at prices ranging from $175 to $200 an acre. The company now owns 2000 acres in one solid block, which in-



Coleman Sellers

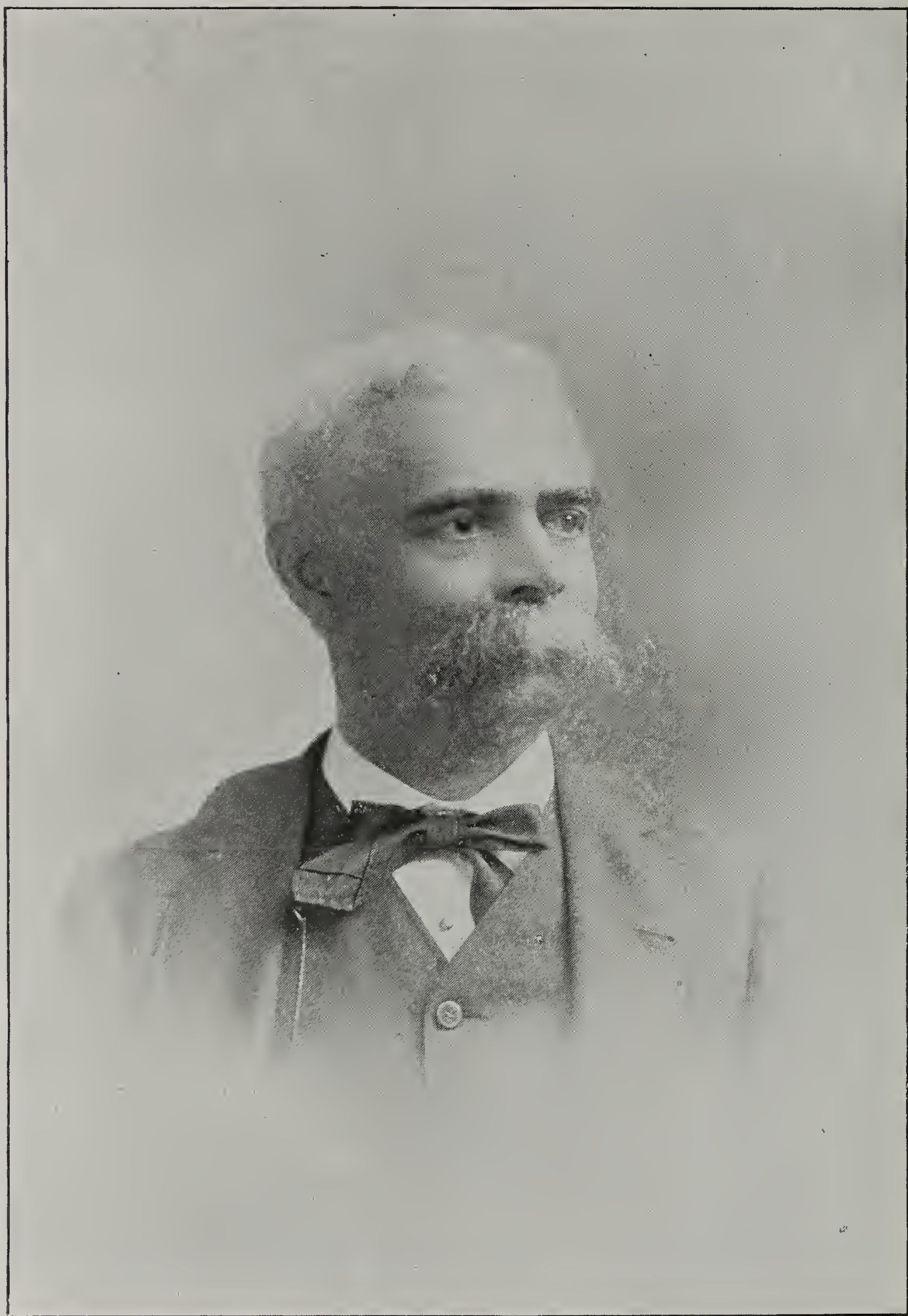
cludes a strip along the river bank 500 feet wide and nearly two miles long. This land could be sold to-day at an enormous profit, but it is the intention of the company to build a busy and vigorous village within the limits of the city of Niagara Falls, for all of this 2000 acres lies to the east of the business quarter of the city and within the city limits. All the river front has been laid off in blocks 400 feet wide for the location of factories, mills, and elevators, while other portions of the district will be reserved for residences to be built by the manufacturers for their own use. The company also intends to build its own terminal railway and receive and deliver cars from any railway reaching Niagara Falls to any mill-site. Besides railway transportation, lake transportation and transportation on the Erie canal are available to tenants of the company.

The company expects to be entirely ready to furnish power to those arranging for its use by taking water from the canal and discharging it into the tunnel by October next.

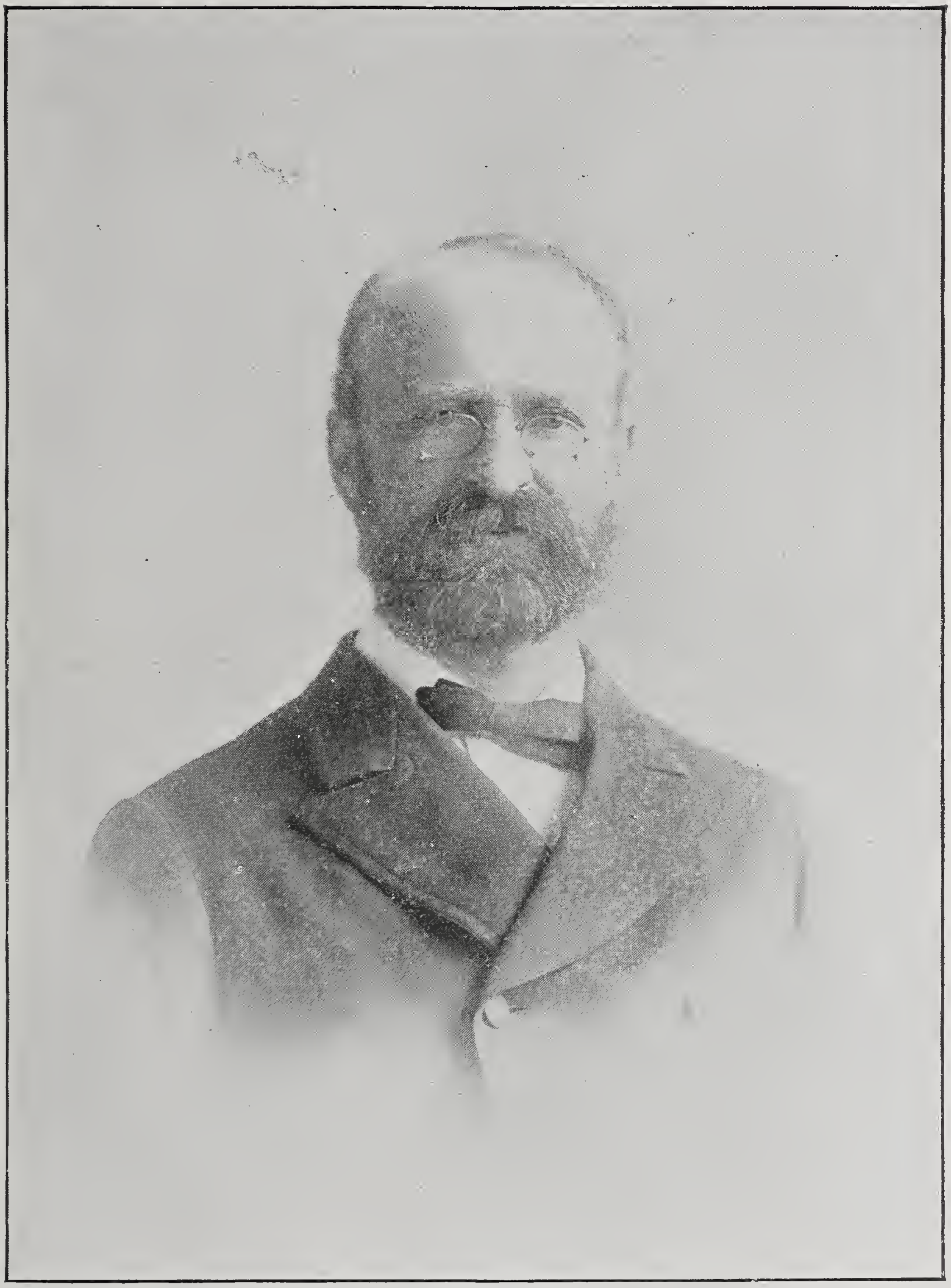
A contract has been closed between the Niagara Power Company and the Cataract Electric Company, of Buffalo, by which the latter acquires the exclusive right to the use of all electricity generated at the new tunnel for distribution in Buffalo. The company will receive the electricity at the city line and distribute it to consumers in the shape of power.

Contracts will be made to furnish power on the company's grounds at the falls for twenty-four-hour days according to the following approximate scale: For 5000 horse-power, $10 per horse-power; for 4500, $10.50; for 4000, $11; and so on down to 300 horse-power, for which $21 per horse-power per annum will be demanded. The cost in Buffalo of a steam horse-power is about $35 per year, so that if the cost of transmission be within present expectations, every wheel in Buffalo can be turned and every building lighted and heated at a much lower cost than at present. The report of the Testing Committee of the Frankfort Exhibition on the Frankfort-Lauffen

THE HORSESHOE FALLS.

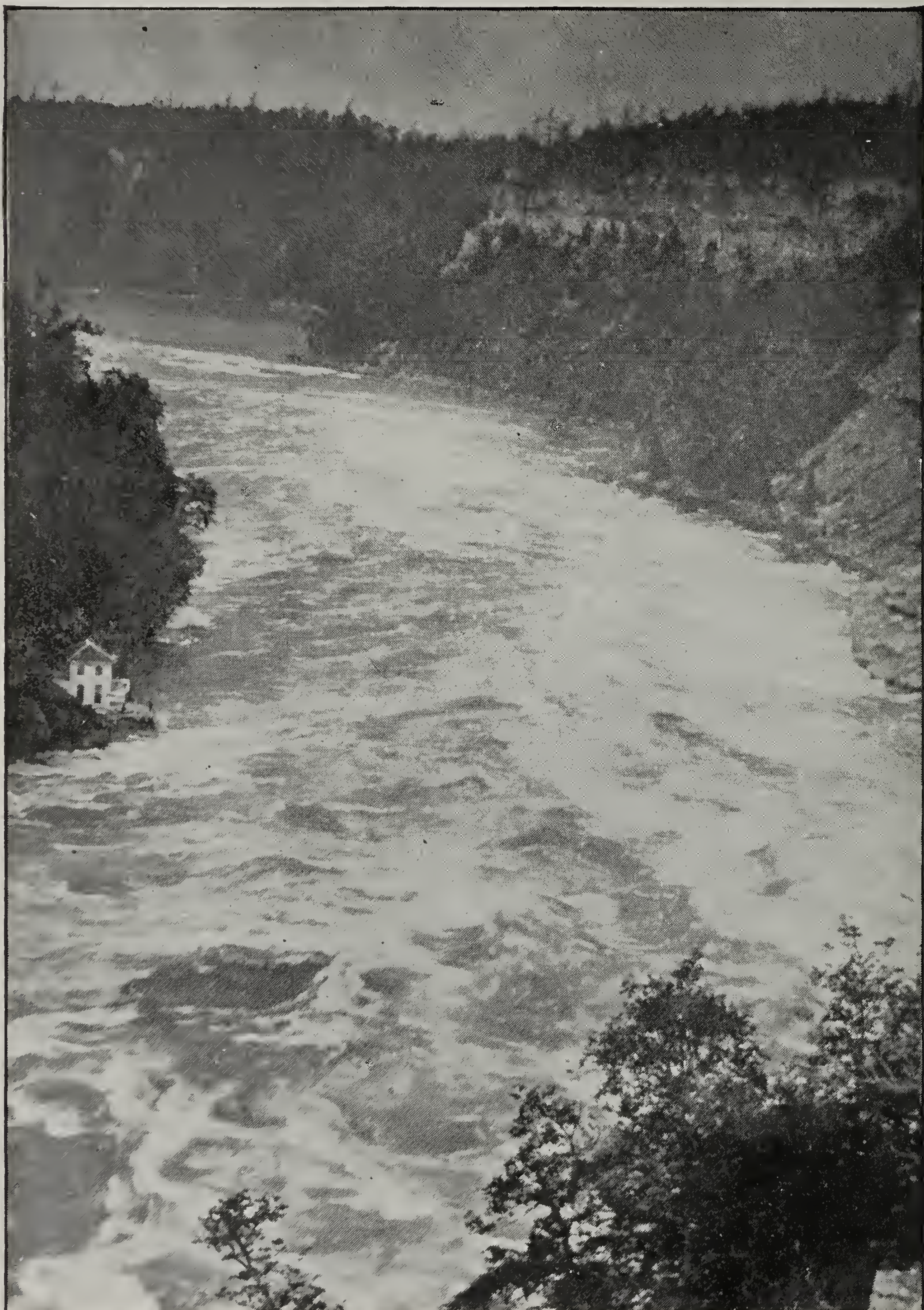


John Bogart



Clemens Herschel

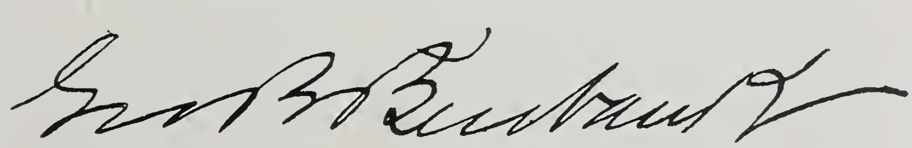
transmission plant shows that a maximum efficiency of 75 per cent. was obtained between the turbine shaft at Lauffen and the terminals at Frankfort; and the various measurements have over 100 miles, it is not at all improbable that it may eventually be similarly brought as far as New York city in a way to be utilized at a much less expense than the present cost of steam-power.



THE WHIRLPOOL RAPIDS.

shown the following losses, viz: In the generating dynamo, 8 per cent.; in the transmission leads, 10 per cent., and in each transformer, 3 per cent. If power can be so supplied to-day for a distance of

It might be mentioned that the only first prize awarded by the International Commission was granted to Messrs. Escher, Wyss & Co., of Zurich, Switzerland, for their method of hydraulic



Albert H Porter

development Two questions, both of vital importance, have been propounded. One was, Is there no possibility of the volume of water now rushing over Niagara being materially decreased as the head waters of the Niagara river are cleared? The other was, Will not the diversion of a portion of the stream impair the beauty of the falls? To reassure those who fear either of the above results, Mr. Clemens Herschel, the eminent hydraulic engineer of the Cataract Construction Company, says that "Niagara Falls, used on 140 feet fall (the fall available on the works now in construction), represents over 3,000,000 effective and available horse-power. The present works are therefore intended, ultimately, to utilize only about 3⅛ per cent. of what Niagara has to give to man's use, and a city of a million inhabitants could be built up utilizing less than 7 per cent. of the available power. So that, from the standpoint of the tourist and the lover of nature, neither the surroundings of the falls nor the falls themselves will lose in beauty by the works contemplated. The mill buildings nearest to the falls will be about 1½ miles above them, and the quantity of water going over the falls will not suffer as much diminution from the normal flow, by the draft for power purposes upon them, as that normal flow now suffers on days when the wind blows up-stream for 24 or more consecutive hours."

Mr. John Bogart, at the request of the President of the Commissioners of the State Reservation at Niagara, considered the question of the effect upon the American Falls of the diversion of the water which may be taken by the tunnel. The entrance from the river to this canal is in the navigable part of the river, about one and one-third miles above the falls and one mile above the head of Goat Island. It is about half a mile above the entrance to the present hydraulic canal and entirely above the rapids. In Mr. Bogart's opinion, the water taken into a canal at that point will not affect the American Falls specially, because the regular regimen of the river will become re-established before reaching the head of Goat Island, where the currents to the American and to the Horseshoe Falls divide. The effect of the water flowing into this canal will therefore be distributed over the whole river, and will not at all be confined to one section of it.

What this effect will be, depends upon the relation of the volume of water taken into this canal to the volume of water flowing in the river.

The amount of flow over the Falls has been variously estimated in past years, but in 1868 the volume was measured by the corps of engineers of the United States army in connection with the survey of the great lakes. The flow thus determined varies from 273,329 cubic feet per second to 280,757 cubic feet per second. It will be proper to call this 275,000 cubic feet per second, or 16,500,000 cubic feet per minute.

The amount that can be taken by the tunnel now under construction, if developed to its full capacity, may be 10,000 cubic feet per second.

This is $3\frac{64}{100}$ per cent of the whole flow.

The actual depth of the water at the crest of the Falls cannot be accurately observed except near the sides of the Falls. The depth varies considerably at different points on the crest. A calculation based upon the observed facts gives $6\frac{22}{100}$ feet (or six feet two and three-fifths inches) as an approximate mean depth of water a very short distance (less than ten feet) above the edge or crest of the Falls when the present mean volume of water is passing over; and $6\frac{7}{100}$ feet (or six feet and four-fifths of an inch) as the depth at the same point when the volume shall be reduced by the amount that can be taken by the tunnel referred to.

Therefore the depth of water along the whole Falls, just above the crest, may be reduced one and four-fifth inches by the diversion of water into the tunnel.

From the operation of a well-known hydraulic law the depth of water directly over the crest will be somewhat less, the velocity being greater; but the decrease of depth at that point, by the diversion of the water, would also be less.

It might be suggested that, as the proposed tunnel may divert $3\frac{64}{100}$ per cent. of the total volume of water, the depth at the Falls would be decreased by the

same percentage ; that is, $3\frac{64}{100}$ per cent. of $6\frac{22}{100}$ feet, which would give a decrease of two and seven-tenths inches. But, in fact, the decreased volume will give a decreased velocity, and therefore a greater relative depth at the crest.

Mr. Bogart, therefore, claims that one and four-fifths inches is the probable amount of the mean reduction in depth at the falls to be caused by the tunnel diversion, and that this amount is so small, comparatively, that it will not affect the depth of water flowing over the falls to an extent that will be visible.

Mr. John Bogart, who is a consulting engineer for the Cataract Construction Co., was born at Albany, N. Y., on February 8, 1836.

In 1853, he graduated from Rutgers College, with the degree of Bachelor of Arts. Mr. Bogart's health on leaving College being delicate, in order to secure the advantages of active exercise he at once entered the Corps of Engineers of the New York Central Railroad. In In this service his health was entirely restored, and he concluded after this experience to adopt civil engineering as his profession. Next he was employed as an assistant in the Engineer's Department of the State of New York. He served throughout the civil war as an engineer, being stationed most of the time in Virginia. After the close of the war he again resumed the active duties of his profession in civil life, and has since been constantly engaged in the direction of engineering works. He was the Chief Engineer of the Brooklyn Park Commission in the construction of Prospect Park. Mr. Bogart was also the Chief Engineer of the Department of Public Parks of the City of New York from 1872 to 1877, and has been connected with public improvements in Chicago, New Orleans, Nashville, and many other cities. He was the Deputy State Engineer and Surveyor during 1886 and till the summer of 1887, when he resigned that position. During the fall of the same year he was elected State Engineer and Surveyor. Mr. Bogart has been connected for many years with the direction of the American Society of Civil Engineers. He is also a member of the Fort Orange Club in Albany, and of the Century, Lawyers' and Engineers' clubs, and Holland and St. Nicholas societies of New York.

Mr. George Barker Burbank, the company's resident consulting engineer, was born March 16, 1844. From 1866–69 he was engaged as rodman and assistant engineer on the Louisville, Cincinnati & Lexington Ry. ; 1869–71 Cincinnati Southern Ry. ; 1871–73 division engineer or assistant engineer on Wisconsin Central ; 1873–74 Chesapeake & Ohio Ry. ; 1874–75 with U. S. Engineers under Col. Wm. P. Craighill ; 1875–76 Cincinnati Southern Ry. ; 1877–81 mining engineer and U. S. deputy mineral surveyor for Nevada ; 1881–4 Resident engineer Denver & Rio Grande Western Ry. and engineer for Rio Grande Western Construction Co. ; 1884 Division engineer for Aqueduct Commission in charge of Dams, etc., at East Branch Reservoir, Brewster, N.Y. Mr. Burbank is a member of the American Society of Civil Engineers.

Mr. Albert Howell Porter, the resident engineer for the company, was born April 19, 1866. During the summer of 1883 he was rodman on the N. Y. State Survey of the Niagara Falls Reservation ; July, 1884, on New Croton Aqueduct in various positions up to transitman in Sept., 1887 ; transferred to Sodom Dam, Feb., 1888 ; from Sept., 1889, to the present time Mr. Porter has been with the Cataract Construction Company. He is an associate member of the American Society of Civil Engineers.

Niagara will continue to roar and tumble, bathe its face in spray, and crown its head with rainbows, but will, nevertheless, be set to work. The zone of consumption of power around Niagara is probably the best that could be selected in this country, and there is no lack of a market within the limits of electrical transmission under the high voltage system, so that there can be no failure to complete the plan. The enterprise may indeed be considered as one of the most notable of those undertaken during recent years, and will be an enduring monument to those who have conceived it and aided in its development.

PROGRESS IN GENERATING HIGH-PRESSURE STEAM.*

By George H. Babcock.

HIGH-PRESSURE steam is merely a comparative term. It depends upon the standpoint. You say in New Hampshire that the White Mountains are high, and in Utah that Salt Lake and the surrounding marshes are low, but really, taking the sea level as a datum, there is very little difference in their altitudes. So in Watt's day 20 pounds per square inch was high pressure, and in fact it was difficult to carry even that pressure with safety on the boilers then used. To-day what is considered high pressure on board a steamboat on a locomotive, or an Ohio river steamboat is looked upon as low. In considering the subject before us we must first define for ourselves the term "high-pressure steam." The standard is continually rising, and in view of this tendency and the present practice we shall be justified in classing anything over 150 pounds as "high pressure," though 250 pounds and even 500 pounds are talked of and attained in some instances.

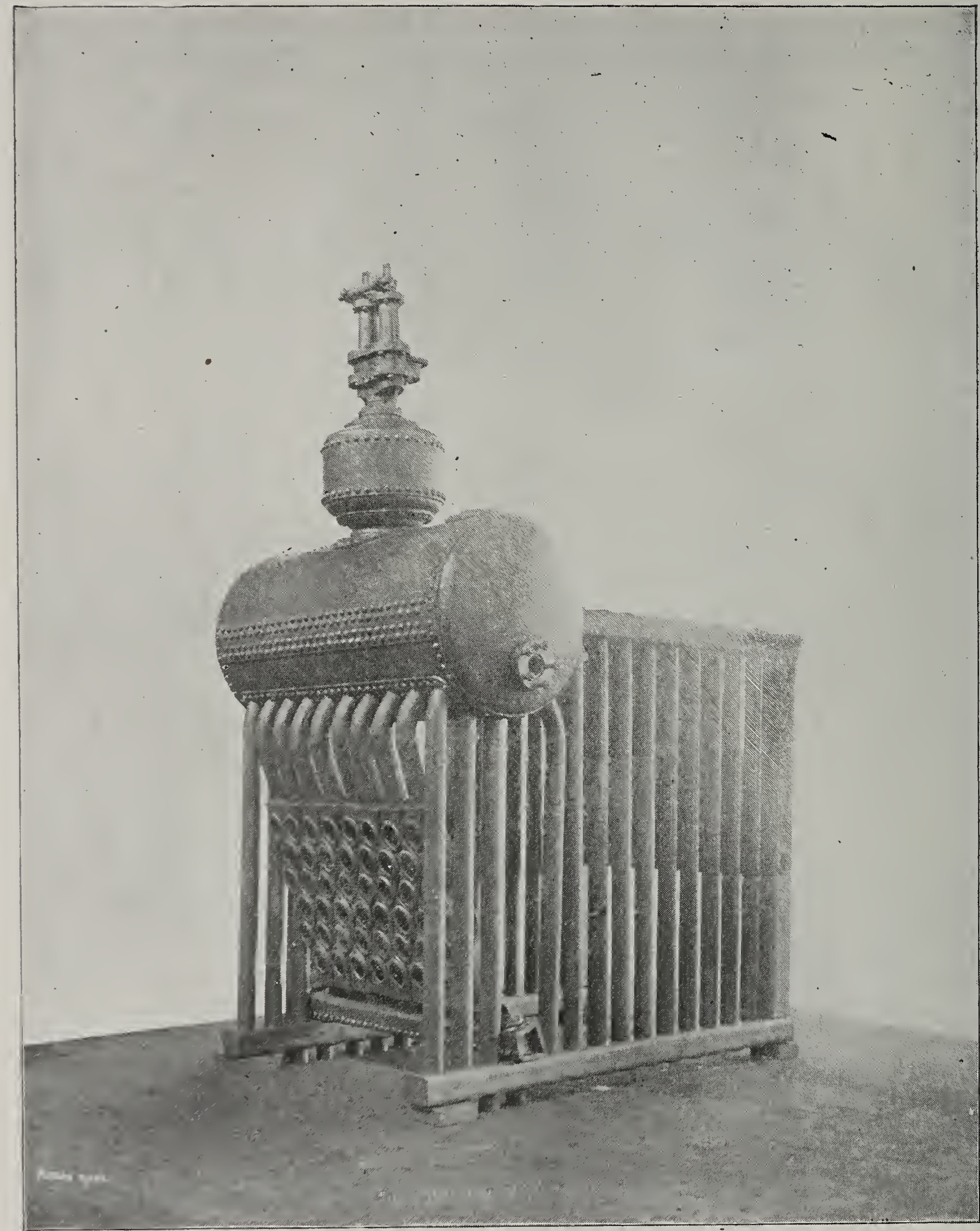
There is nothing new or modern in the idea of the use of steam at high pressures, particularly if we accept the definition in vogue at the time; indeed, there seems to have been a tendency from the very first to employ high pressures. As early as 1697, Savery made an engine which forced water against 80 feet head—say 40 pounds pressure—and stated that he could force it against 1000 feet if he could get vessels strong enough to stand the pressure. In 1766, Blakely made the first sectional boiler in order that he might carry higher pressures, and though we find no record of what that pressure was, the fact that the experiments were terminated by an accidental bursting of one of the steam vessels through the force of the steam, at a pressure much below what had been proposed, shows that the intention was to use very high pressure.

*Lecture delivered at Sibley College, Cornell University.

Oliver Evans may be fairly credited with the earliest use of what may be termed high-tension steam. In 1787 he obtained a patent from the State of Maryland for a high-pressure engine, but it was not until 1800 or 1801 that he secured funds to construct one, with which he drove a plaster-mill, carrying a pressure of 100 pounds. In 1840, John Cox Stevens built a pipe-boiler (which is still in existence) which he put on a boat, and worked at a pressure of 50 pounds. In 1815, Trevitheck, in Wales, built a locomotive which used as high as 145 pounds of steam on occasions, and in 1815 he had a pumping-engine running at 100 pounds, though he did not use or recommend, as a rule, more than 25 or 30 pounds, which was then called "high pressure."

Jacob Perkins, however, was the great apostle of high pressure, for he and his sons have been working at and advocating extreme pressures for the last seventy years. In 1822 he designed a boiler into which he injected water, getting steam at enormous pressures; in fact, he is said to have heated water red-hot, generating a pressure which he estimated at 56,000 pounds to the square inch. He built an engine and boiler for using steam at 700 pounds, and succeeded in supplying steam at that tension, but the temperature was too high for any lubrication he could command in the cylinder. Traces of experiments by the Perkinses are scattered all along from that time until now. In 1872 they built a tug, the *Filga*, which used 250 to 260 pounds, and in 1880 the *Anthracite*, built by them, crossed the Atlantic and created some stir in engineering circles. Her boiler was a modified form of that of 1822, with the injection feature abandoned, and the pressure carried was from 300 to 400 pounds per square inch.

In 1850-60, J. W. Rowan built a number of ships with compound expansion engines and high-pressure boilers, using steam at 100 pounds and above, but the ships were not a commercial success.



BOILER FOR STEAM YACHT "REVERIE.'
(Fig. 6.)

Notwithstanding these instances of the use of usually high pressures for the times, low pressures remained the general practice, particularly in marine service, until a quite recent period. The usual pressure used at the commencement of ocean steam navigation was but 2 to 4 pounds above atmosphere. Thirty years later the Cunard Line employed but 15, while a few other vessels went as high as 30, and some, the North river steamboats, up to 50 pounds. At this time, 1867, a list of English steamers was published, in which the pressures used in 45 vessels, including several tug-boats, were given, showing an average for the whole of but 27.3 pounds. The highest was 60 pounds, the lowest 14.

The beginning of what may be termed the era of high pressure in steamships was ushered in about a dozen years ago by the advent of the *Arizona* with 86 pounds, soon followed by the *City of Rome*, the *Normandie*, and *Furnicia*, each carrying 90 pounds. Then came the *Alaska* and *Oregon*, the *Umbria* and *Etruria*, the *Ems*, etc., with 100 to 110 pounds, and now we have the *City of New York*, the *City of Paris*, the *Normannia*, *Prince Bismarck*, and *Teutonic* and *Majestic*, all carrying 160 to 180 pounds.

Locomotives have been ahead of other forms of engines from the first, in this matter of high pressure. As said before, Trevitheck, in 1805, ran a locomotive with 145 pounds of steam, as an experiment. At the famous Rainhill competition in 1829 the pressures were limited by stipulation to 60 pounds, which at that time was thought to be pretty "high." The earlier locomotives of this country, however, used generally about 100 pounds, gradually raised to 125 pounds, which was the average some years ago. Now the later locomotives carry 180 pounds, and use compound cylinders.

In stationary engines, pressures higher than 60 to 80 pounds have been very rare, though Galloway said that it was no uncommon thing in his day (1830) to find boilers in this country carrying 200 and 300 pounds. It must be that then as now things were sometimes seen in inverted perspective, distance lending magnitude to the view.

Mr. Wm. Fairburn is quoted as saying that "danger in the use of high-pressure does not consist in the intensity

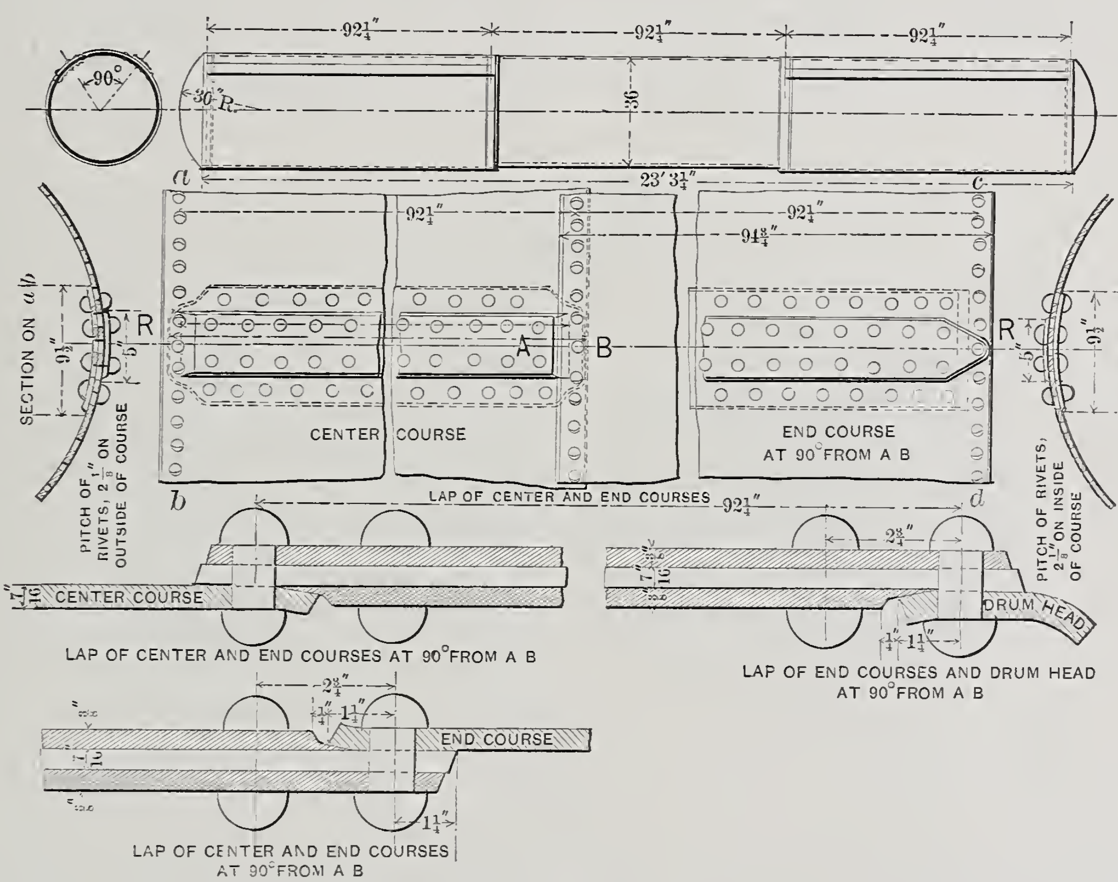


FIG. I.

of the pressure to which the steam is raised, but in the character and construction of the vessel that contains the dangerous element."

James Watt limited his pressures to about 2 pounds above the atmosphere, mainly because the character of the boilers at his disposal was not adapted to more. We talk of large boilers now, but the largest of this age are pigmies compared with the one Watts put at work at Dolcoath mine. It was 24 feet in diameter and 24 feet high, and its furnaces held thirty tons of coal at one time. It was the cylindrical boilers of Oliver Evans and Trevitheck which permitted them to increase the pressure. Probably one reason why marine engines were so far behind locomotives and stationary engines in using high-pressure was on account of the large boilers then and still used, as a rule, for ocean-going steamers. In 1867 *Engineering* said that the limit of pressure safe to carry on large shell marine boilers was reached at 50 pounds. The unwisdom of such predictions is apparent now, upon seeing 16-foot boilers running at 180 pounds, with apparent safety. I say "apparent" because, should one of them once explode, the results would be doubtless as unprecedented as are the pressures. In 1867 a boiler of the Greek steamer *Bouboulina*, an old blockade-runner revamped, exploded on the Mersey, literally tearing the ship in two, blowing the bow in one direction, the stern in another, and the boilers at right angles thereto. It was said to have had but four pounds of steam on at the time. How much worse would be the result of the explosion of one of our modern marine boilers, carrying 180 pounds steam.

But the fact that we do not have any more explosions now in proportion to the number of boilers used. than occurred when low pressures were carried, shows that progress has been made in "the character and construction of the vessels containing the dangerous element," to quote again Sir Wm. Fairburn's words. It is not merely that engineers and the public have been educated by usage to a point where they can witness without alarm what would have caused them to flee for their lives but a few years ago. There has been real progress in boiler-making, and in the materials used therefor, so that these higher pressures are really as safe as 50 pounds may have been in the boilers of 1867. Improved materials have much to do with it—better workmanship more. In those days it was quite impossible to get sheets of homogeneous metal of a quality demanded by modern boiler-work, but had they been obtainable, neither the tools nor workman could have been found to make them into the modern boiler. Punching-machines, drifting-pins, and riveting-hammers were about the only tools then required for a successful boiler-works, and hydraulic or machine rivet-

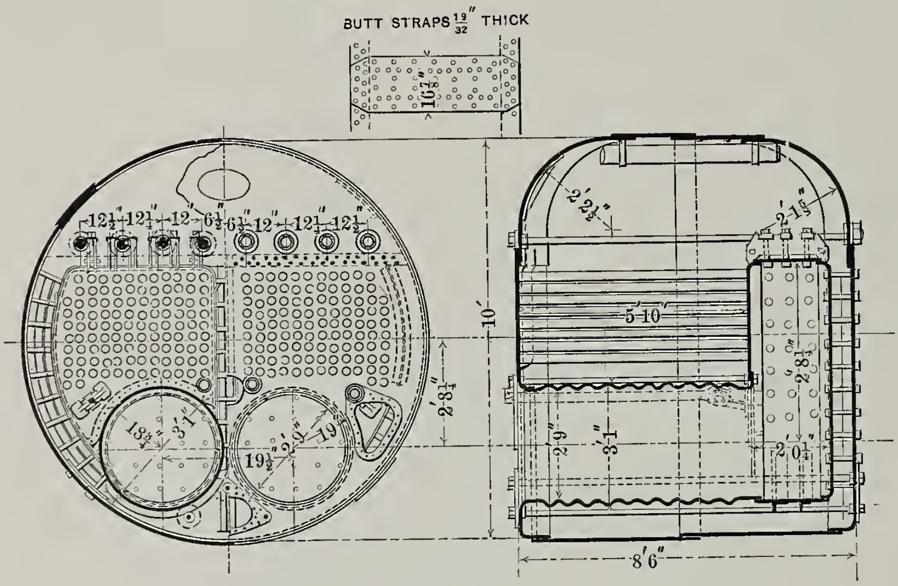


FIG. 2.

ting was in its infancy. For a long time machine work was decried as inferior to work done by hand, and even now "fossils" may be found who will still echo that cry, notwithstanding it is a well-settled fact that only machine riveting, and that of the best, is adapted to carrying the high pressures demanded in these days.

This cry that the days of the fathers were better than these, and their ways more to be desired than those of their degenerate sons, has been heard for more than three thousand years, but nevertheless the world is continually improving, though it is true that in mechanics, as well as in organic life, there are frequent reversions to the original type, and every age witnesses so-called "improvements," which are in reality mere steps backward.

The character of the riveted joints has much to do with the ability to carry high-pressure steam in the boilers of to-day, for though in the best types of boilers much of the work is without rivets, yet even they have steam and water reservoirs which have to be put together in that manner. Welding the joints of boilers has not yet been brought to the point where it can be safely depended upon. It is true that welded furnaces are in common use in the high-pressure marine boilers of the principal ocean lines, but the joints in these are exposed only to crushing strains. So far, welded drums for internal pressure have not proved satisfactory. What may yet be accomplished by electrical welding, or possibly spiral welding, remains to be seen.

A riveted seam for high pressure requires great care. The edges of the plates should be bent to the proper curvature before being rolled into form, else the seam will be flat and the contact imperfect. The best method of doing this is by a hydraulic press and dies, through which the sheet is passed until the whole length is treated. If the edges are heated for this process, so much the better, as the heating not only anneals the metal, but loosens any scale there may be on the surface, which would tend to prevent close contact. The straps—for the seam must not be simply lapped—must be treated in the same way. When these are fitted so as to lay as closely to the shell as possible without bolts, then enough holes are to be drilled, somewhat smaller than the rivets, to admit of sufficient bolts being put in place to bolt the whole together snugly, after which the rivet-holes are drilled through both thicknesses at one operation. As the work progresses turned bolts fitting the rivet-holes are driven in every three or four holes, and drawn up snugly. The circular seams, if there are such, must be first drilled, starting in the center of sheet and working toward edges, so that the sheets may be snugly held together before the

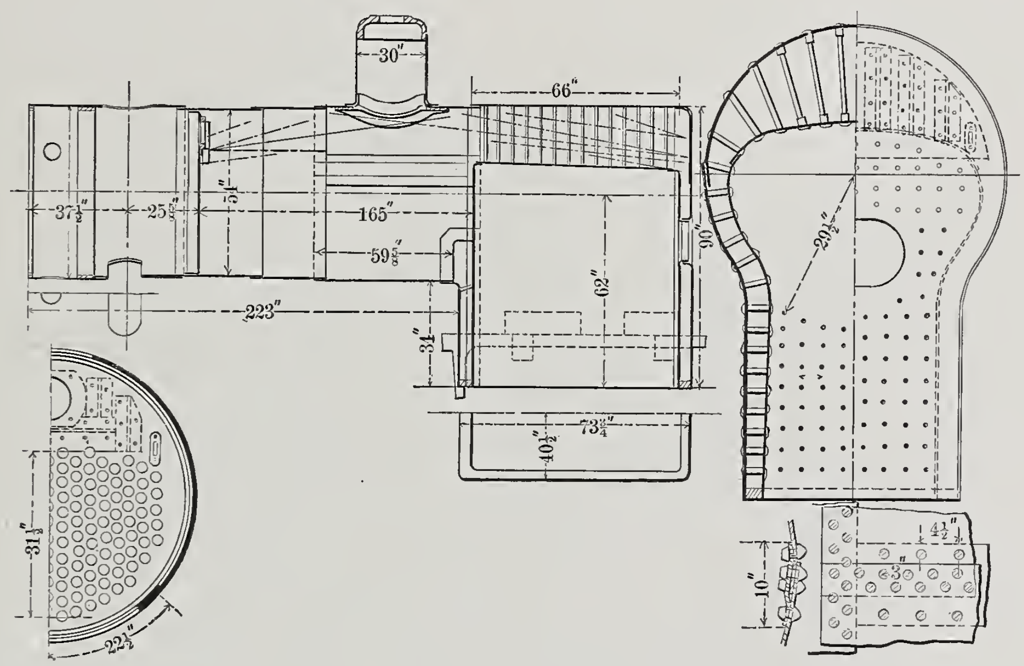


FIG. 3.

longitudinal seams are drilled, and the bolts provisionally placed in these longitudinal seams must be slackened to allow the sheets to adjust themselves as the circular seams are drawn up. As the rivet-holes are drilled, if the bolts do not readily draw the sheets into close contact, means should be used to set the plates up iron and iron. After all the holes are drilled in this manner, all the bolts should be removed, the plates taken apart, and the holes countersunk on both sides to remove any fins left by the drill, after which they must be cleaned thoroughly from all chips or borings. The parts are then again assembled, and the rivets driven from cold, and it is not an uncommon thing to find the heads of hand-driven steel rivets dropping off from this cause. Iron does not seem to possess that quality.

Fig. 1 shows the character of seam, and the arrangement of rivets best adapted for high pressures, say 200 to 300 pounds, being both strong and tight. It is a double strap, the inner one wider than the outer, and four rows of rivets, as shown.

Fig. 2 shows a marine boiler for U. S. Cruiser No. 2, for 160 pounds pressure. It is of the approved marine type, and with single-strap, butt-riveted joints, which will answer for that press-

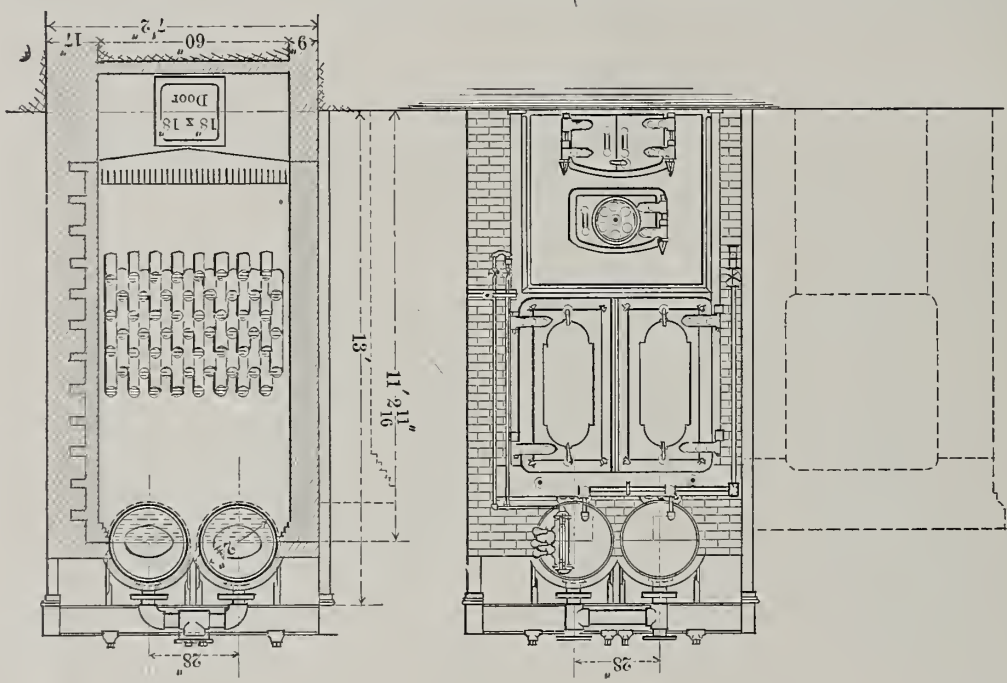
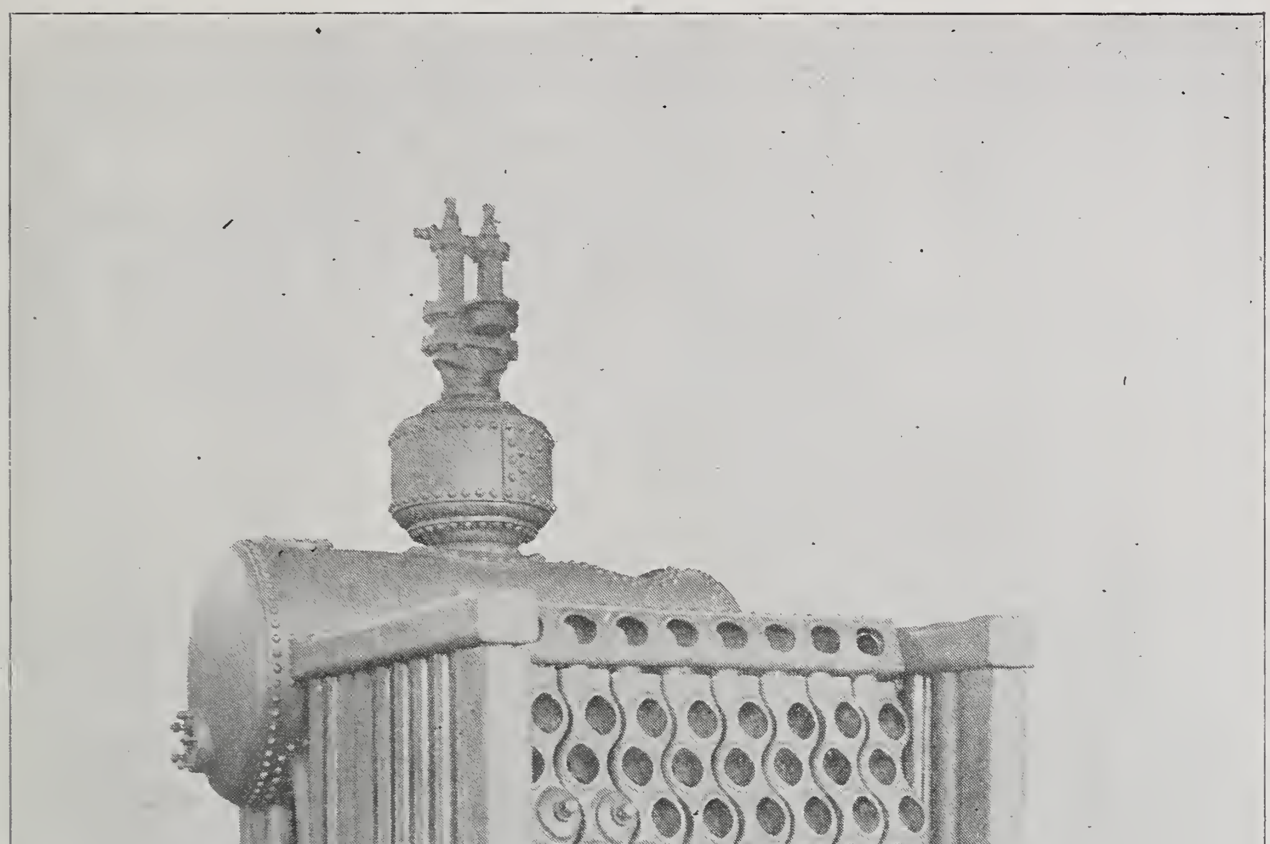


FIG. 4.

center of seams outward, all riveting being done by machine, except such as the machine will not reach. Flange-heads must be made a driving fit, otherwise they cannot be drawn up tight. The quality and kind of rivets need also to be carefully looked to. When driven by machine and finished hot, steel rivets are the best, but if to be driven by hand iron rivets only should be employed. The reason for this is that with all steel there is a critical temperature, at which if worked it becomes quite brittle. This is known as a "black heat," that is, just below red. Probably it varies with different steels, but that it exists is without question. In riveting by hand it is customary to hammer the rivets until ure. It will be noticed that flat surfaces have been avoided as much as possible.

In the locomotive for 180 pounds pressure, shown in Fig. 3, the joints are also butted with straps, and the flat surfaces stayed every 4 to 4½ inches. This is the latest and most approved construction of the Baldwin Locomotive Works.

These boilers, Figs. 2 and 3, illustrate very fully the difficulties which beset the engineer when designing boilers of the shell variety for such high pressures, and point to the desirability of resorting to some construction in which large shells and flat surfaces may be dispensed with. Such a construction is found in



BOILER FOR STEAM YACHT "REVERIE."
(Fig. 7.)

the water-tube boiler, but it is by no means easy to design a water-tube boiler having all the requisites for high pressure, particularly for marine use, while for locomotive purposes they are almost out of the question. For stationary use a large number of water-tube boilers are working at 160 pounds and above. Fig. 4 and 4a shows one for 500 pounds at the works of the Consolidated Safety-Valve Co., Bridgeport, Conn.

For marine purposes little as yet has been done in water-tube boilers, though very much has been attempted. The failure of the boilers on the *Montana* and *Propontis* was so complete, and, being supplemented by many other unsuccessful attempts to introduce water-tube boilers on shipboard, it has tended to make ship-owners very conservative in that regard, though it is almost or quite universally admitted that the coming marine boiler for high pressures must be of the water-tube type. The large number of Belleville boilers placed on French steamers, notwithstanding the serious difficulties met with in their use, and the attempt of the United States government to apply a water-tube boiler on one of its cruisers, as also many attempts at water-tube boilers for yachts, more or less successful,—generally less,—emphasizes this demand for a practicable water-tube marine boiler. The conditions necessary are :

1. It must be all wrought-iron or steel, not only because of the advantages of such construction, but because no other would be passed by government inspectors.

2. It must be without stayed surfaces, and yet should have a furnace surrounded by water, as purely brick-set furnaces are scarcely admissible on shipboard.

3. It must be convenient of access for cleaning outside and in, and for repairs, with the least stoppage in case of accident.

4. It must be a "free steamer," and yet economical in the use of coal,—two points of excellence not easily reconcilable.

5. It must have sufficient steam capacity to prevent too rapid fluctuations in pressure when handled by ordinarily skillful firemen.

6. It must be economical in room, and to this end the grate should occupy, as nearly as possible, the whole floor space.

HYDRAULIC FORGED STEEL HEADER.
(Fig. 8.)

7. It must have a free circulation of water, uninfluenced by the motion of the ship, and not be liable to foam or too rapid changes of water-line.

8. It must be mechanical in construction, and not liable to get out of order.

9. It must be reasonably safe from destructive explosion,—that is, its construction must be such that the rupture of any part will not endanger the safety of the ship.

10. It must be capable of carrying pressure up to 250 pounds, without being excessively heavy.

11. It must be capable of furnishing dry steam under all circumstances.

It need scarcely be said that a boiler fulfilling all these conditions beyond criticism has not yet been made, and it may devolve on one of the young gentlemen present to furnish the remaining

links in perfecting the high-pressure boiler. The nearest approach to it which I am able to show you to-day is in some of the boilers I am now about to exhibit.

Figs. 5 and 6 are two views of the boiler of the steam yacht *Reverie* as it was partially erected in the shop before delivery. The sinuous headers, as well as the square tubes, are all wrought-steel, made by hydraulic forging, and all parts are connected by expanded wrought-iron nipples. The water-tubes are set in groups of three, so as to be accessible from the hand-holes. The furnace sides are flanked by vertical tubes, fire-bricks fitted to the tubes being placed between them, outside, their whole length. When in the yacht these sides, and in fact the whole boiler, is covered with two thicknesses of sheet-iron enclosing magnesia for a non-conductor. This boiler has been in use two seasons, steams freely and economically, carrying 225 pounds in regular work, is perfectly tight, and so far is quite satisfactory. A similar boiler has been in use on a tug boat on the Seine, owned by La Compagnie de Navigacion du Havre à Paris et Lyon, for nearly three years, with satisfaction.

Figs. 7 and 8 is a similar boiler for larger powers, having 2025 square feet of heating surface and 45½ square feet of grate. In this boiler large tubes are placed next the fire, and smaller tubes above, for a better extraction of the heat, and to permit a combustion chamber between. It will be noticed that the two banks incline in opposite directions. This is important, neutralizing the effect upon the water circulation of any pitching of the ship. This drawing will bear close study, as embodying the best results of many years study and experience in the adaptation of the water-tube boiler to high-pressure marine purposes.

The details of this boiler are worthy also of your attention, the hydraulic forging particularly being something greatly in advance of anything heretofore attempted in that line. It is shown in perspective in Fig. 9. This is made out of a sheet of steel, passing through several operations, and three principal heats. At the first heat it is bent in dies into a square tube with rounded corners, and the lap on one side. It is then brought to a welding heat, slipped into a mandrel, and pressed through the welding rollers, from which the mandrel is then removed, and a sectional mandrel substituted, when it is slid into dies in a powerful hydraulic press which corrugates it into the form shown. It is then reheated, after small holes have been drilled where the tube-holes are to

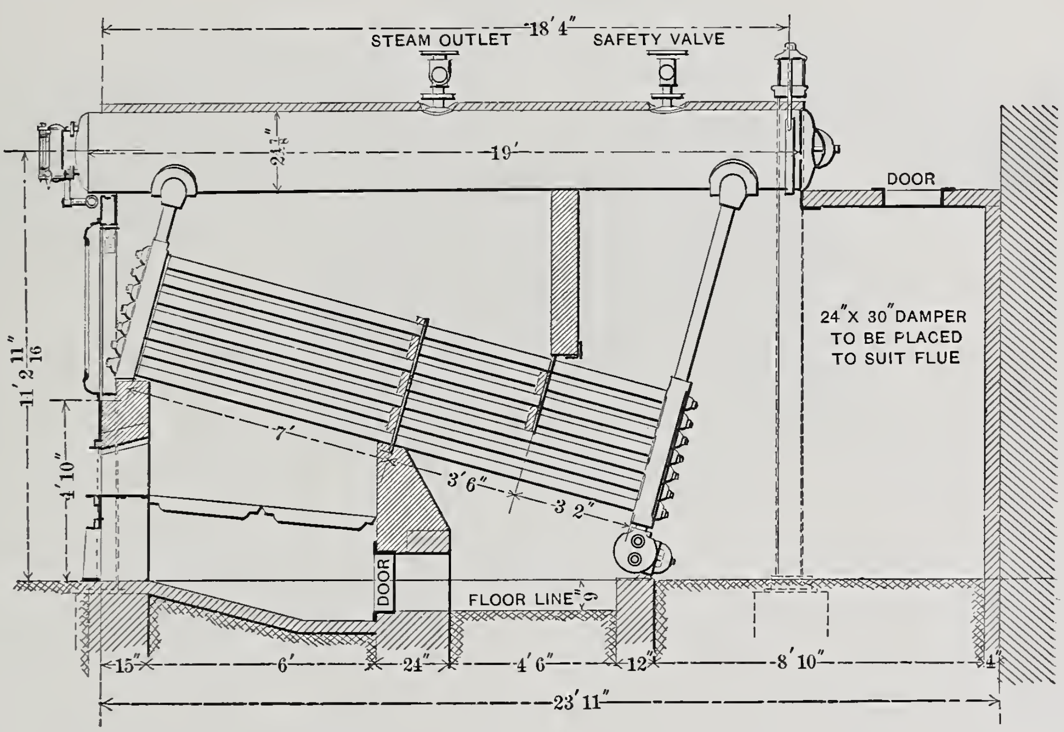
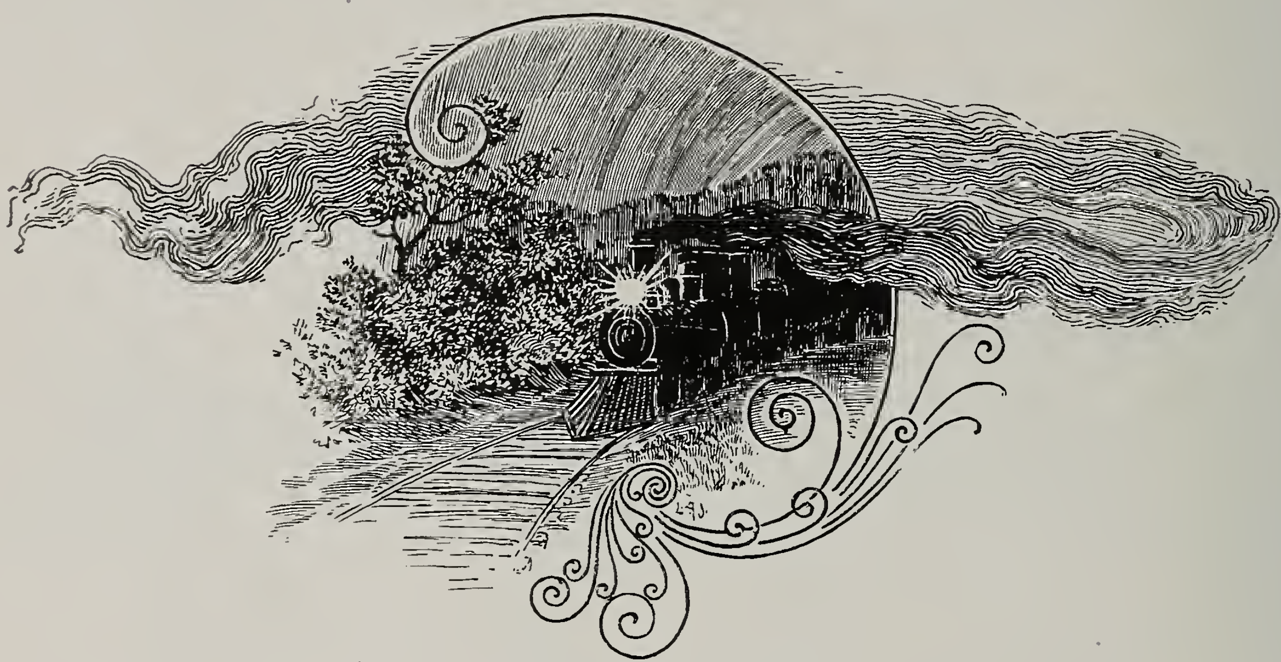


FIG. 5.

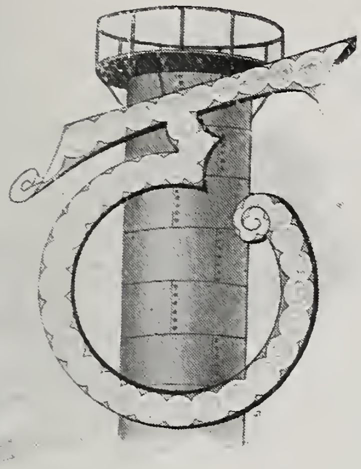
to be, and placed in a press which, working through these holes, embosses the spaces for hand-holes. The ends are then welded in and the machining done, which consists of drilling the tube and hand-holes, and facing the bosses for hand-hole covers.

There is also on the platform a specially fine hydraulic forging for the cross-box shown in Fig. 3, for connecting the tubes to the steam- and water-drum. This is forged from a single sheet at one operation, for those of ordinary projection, but for those having more projection from the cylinder-line sometimes more operations are required.



RECENT CHANGES IN THE PIG-IRON INDUSTRY.

By William Kent, M.E.



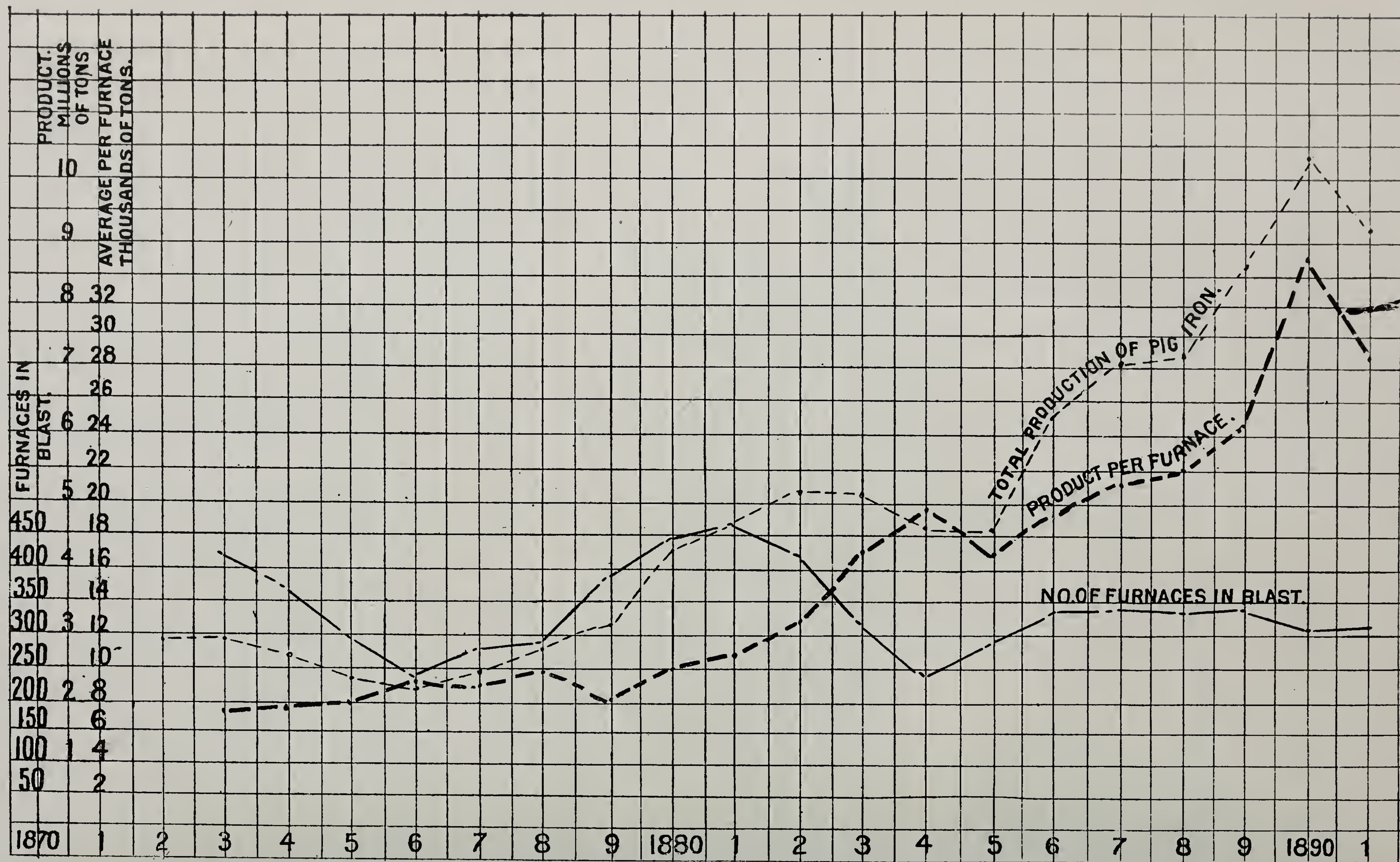
THE year 1873, famous as the year of the financial panic following the failure of Jay Cooke & Co., and as the first year of the five years financial depression, is also notable as the beginning of a period of changes in the condition of the iron industry in the Uuited States which in less than twenty years have caused it to be practically revolutionized. The changes have been geographical, as to location of the industry; technical, as to improvements in methods of manufacture; financial, as to bankruptcy, liquidation, or other relinquishment of business by nearly, if not quite, half of those engaged in it, and as to the formation and consolidation of new companies; and revolutionary, as to the extinction of the old direct processes of making iron in the forge, and as to the substitution of Bessemer and open-hearth steel for wrought iron, and of anthracite and coke pig-iron for charcoal iron.

The wonderful development of the Bessemer steel industry during this period, the product advancing from less than 200,000 net tons in 1873 to over 4,000,000 in 1890, and that of the pig-iron industry advancing from 2,868,278 tons in 1873 to 10,300,028 tons in 1890, and the fact that the United States has now taken the first place among the nations in the production of both iron and steel, are matters of common knowledge. It is known to but few, however, outside of those immediately interested in the trades, through what struggles and what disasters this wonderful result has been reached in so short a time, and how the inexorable law of the "survival of the fittest" which has brought forth iron and steel companies of $25,000,000 capital, has swept out of existence hundreds of once flourishing concerns, and condemned to ruin hundreds of once active blast furnaces.

Fortunately the iron trade of the United States has a historian, through whose labors we are enabled to get facts and figures which represent some of the changes in the iron trade. For over twenty years Mr. James M. Swank, of Philadelphia, the Secretary of the American Iron and Steel Association, has been gathering statistics of the iron and steel trade, and publishing them in his annual reports. Since 1873 he has published about every three years a directory of the iron and steel works of the United States, the last one having been published during this year. He has also just published a second edition of his book, a "History of Iron in all Ages." There is therefore no lack of statistical material by which to stimulate our memory of what we have seen of the changes in the iron trade in the past twenty years.

It is proposed here only to glance at the changes in the pig-iron industry, and chiefly those in the anthracite region, the region in which the changes have been of the greatest importance.

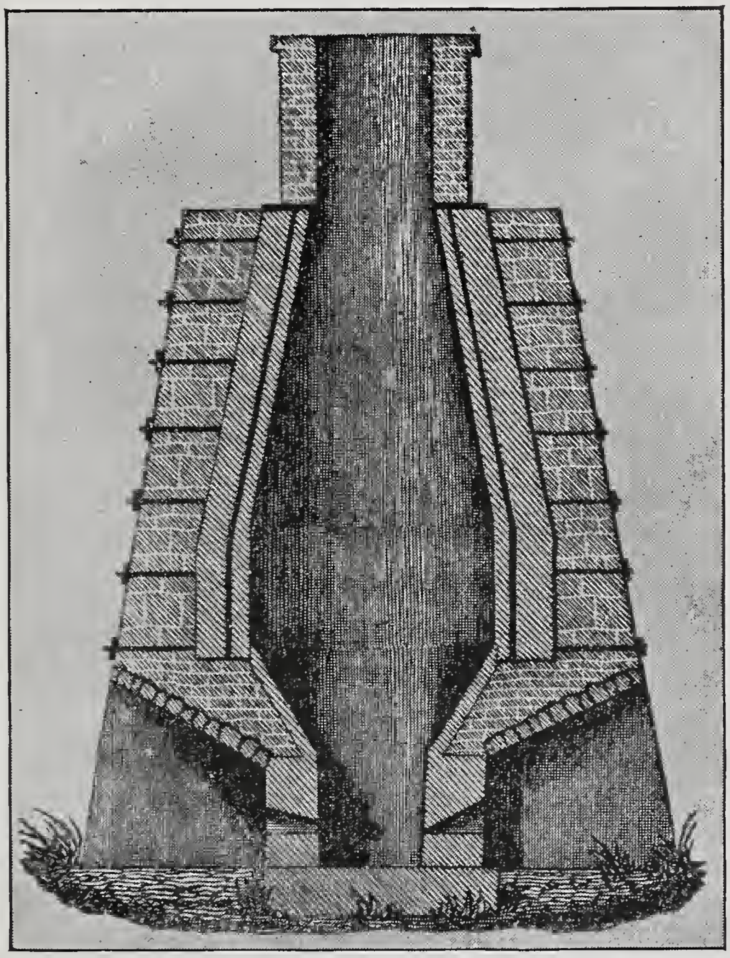
In 1873 the ordinary anthracite furnace was a massive stone structure, about fifty feet in height, well shown in the illustrations herewith taken from Osborn's Metallurgy, published in 1869. A good furnace of this type, with what was in those days considered a good equipment, could make about 300 tons of iron per week, with an expenditure of about 2 tons of anthracite coal per ton of iron, but the average furnace produced only about half of that quantity. The production of pig-iron in the United States increased from 931,582 net tons in 1865 to 2,854,558 tons in 1872, and to meet the extraordinary demand nearly 100 blast furnaces were built in 1872. That was before the day of large furnaces and powerful blast, however, and about the only difference



PRODUCTION OF PIG IRON, FURNACES IN BLAST, AND AVERAGE PRODUCT PER FURNACE.

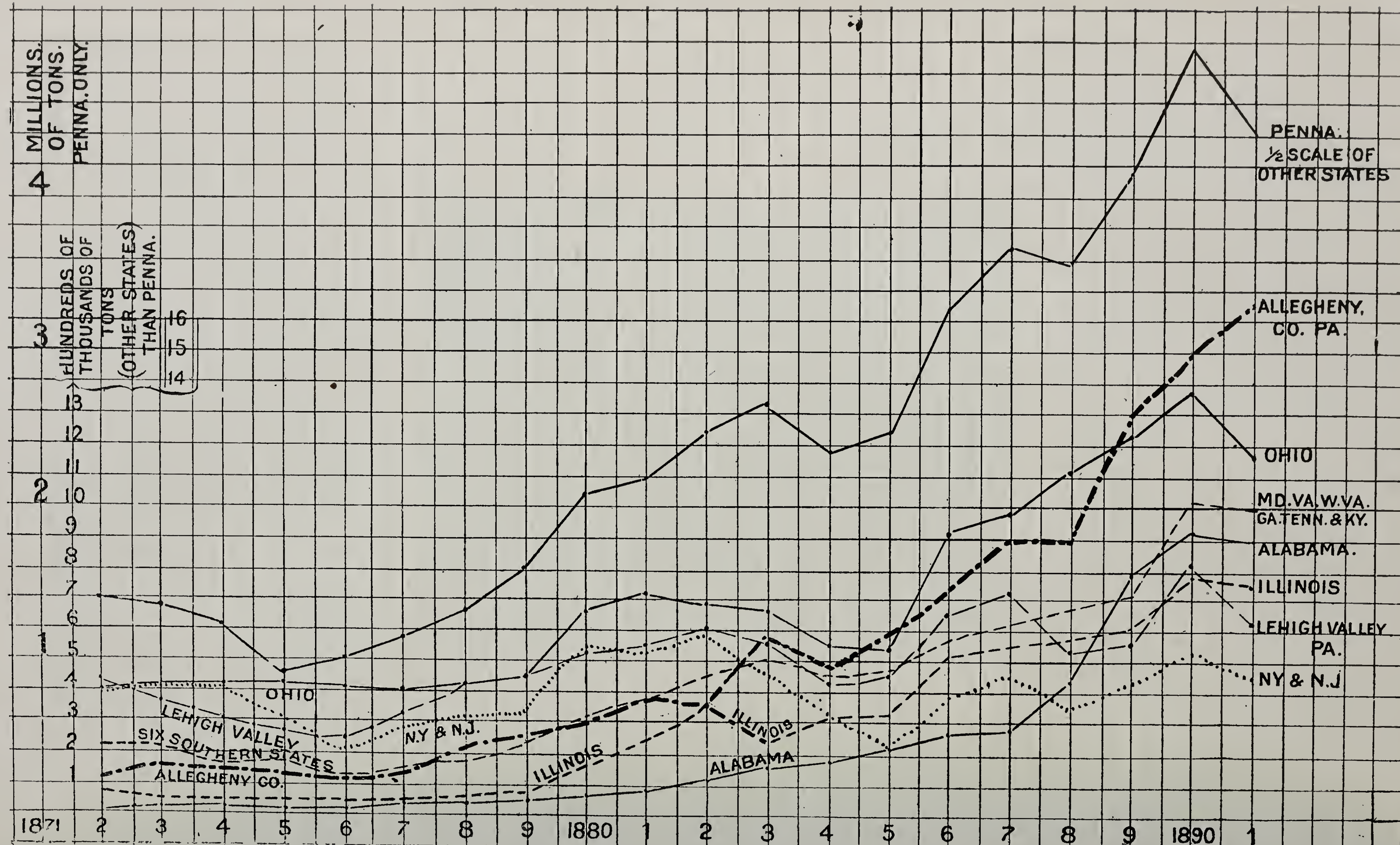
between the new furnaces and the old was that they were constructed with a sheet-iron external casing instead of heavy stone masonry. The hot-blast stoves which had been formerly placed above the furnaces, as shown in the cut from Osborn, were brought down to the ground, and a large gas-pipe, or "downcomer" brought the waste gas to them.

In 1872 the two Isabella furnaces, near Pittsburgh, using Connellsville coke as fuel, were built by Mr. Benjamin Crowther, who, contrary to all advice and experience, believed that he could build a furnace to make 500 tons per week. Shortly after they were built one of them made over 700 tons in a week. In 1877 Mr. Crowther told the writer he hoped to live long enough to see a furnace make 1,000 tons a week, but he has lived long enough to see several furnaces near Pittsburgh that each make regularly over 2,000 tons per week. This is one indication of how rapidly the capacity of a furnace has been growing. The record made by the Pittsburgh furnaces, however, had but little effect in stimulating the anthracite furnaces to increase their product. The panic came in 1873, the price of No. 1 pig iron in Philadelphia dropped from $54 per ton in September, 1872, to $42½ per ton in September, 1873, the month of the great failure, and never stopped declining till it reached $16½ per ton in November, 1878, when the country woke up to find it had recovered from the panic. During this long period of depression there was not much encouragement to build blast furnaces or to spend money improving old ones. The production of pig iron decreased from 2,868,278 tons in 1873 to 2,093,236 tons in 1876, and the number of furnaces in blast decreased from 410 to 236.



ANTHRACITE FURNACE AT READING, PA.

In 1877 Mr. E. C. Pechen thus described the status of the blast furnaces: "The American furnaces of to-day may properly be divided into three classes. 1st. Those of antique construction and small capacity that have outlived their

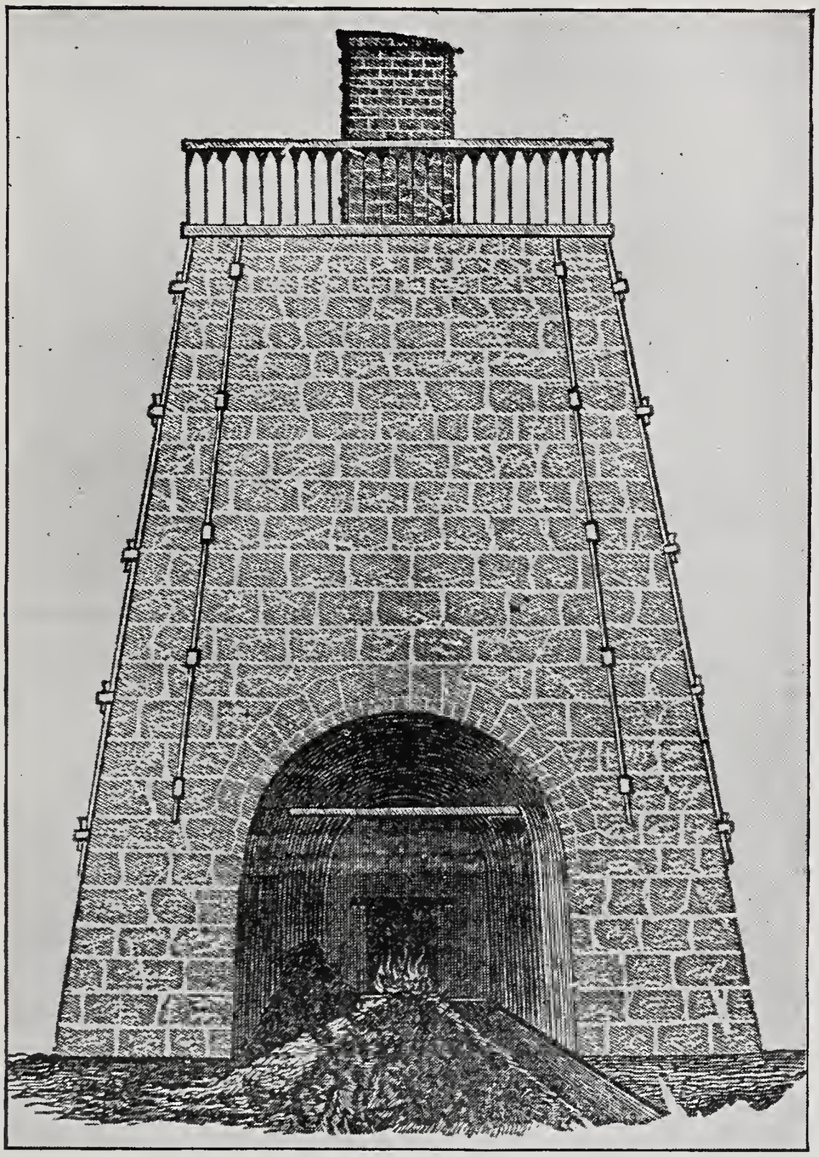


GEOGRAPHICAL DISTRIBUTION OF THE PRODUCTION OF PIG IRON.

usefulness and opportunity find their occupation gone, and are now worth simply the price of scrap. 2d. Those of fairly modern construction but unfavorable location, which, under forced sales, are in the hands of new parties at nominal figures, together with those of older style, but exceptionally well located. 3d. Those combining the advantages of modern improvements, large capacity, and good location. * * * There is something at work far deeper and more complex than mere overproduction,—it is the deadly struggle between the old and the new, between modern and obsolete ideas ; it is the establishment of a vital industry on a new basis ; it is the re-adjustment and re-location of the iron business of the United States.''

Mr. Pechen's words have proved prophetic, for the re-adjustment and re-location have taken place, and the struggle between old and new ideas has resulted in establishing the industry on a new basis.

Many new ideas have had a share in this re-establishment. In 1877 the value of chemistry as an aid in the manufacture of iron was only beginning to be felt—now it is recognized as indispensable. In that year the owner of a blast furnace in Ohio said to the writer : ''I don't believe in chemistry. The way to test an iron ore is to put it in the furnace and try it.'' He had put ore into his furnace and had produced an iron which was the wonder of the surrounding country. It had large mirror-like facets, like spiegeleisen, was as brittle as glass, and was entirely unsalable. It was, in fact, a very highly



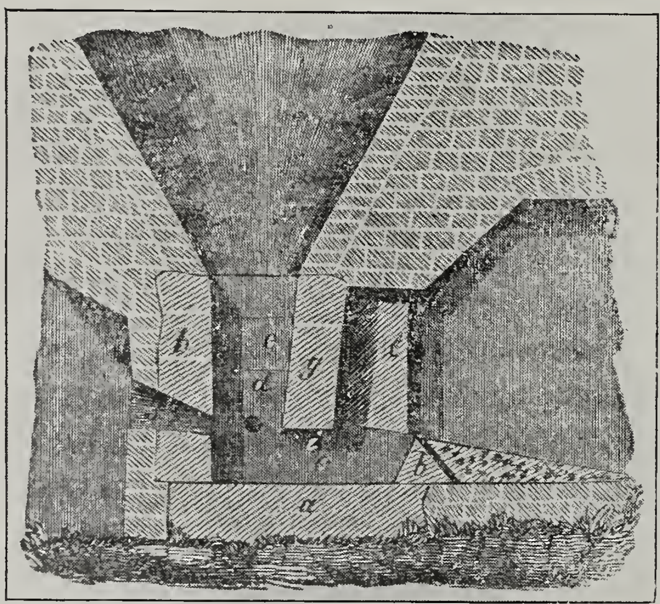
FRONT VIEW OF A BLAST FURNACE.

silicized iron,—unsalable because its chemical composition was not known. To-day the same iron, with its contents of silicon known, would find a ready market as a "softener."

Another idea that slowly penetrated the minds of furnace owners about that time was that of the closed front. Heretofore it had been the custom to open the front of the furnace twice a day, and dig out a mass of coal and unfused slag and iron, chilling the furnace at each such operation, and retarding its production. Some one found that if the furnace was never opened but kept hot enough everything in its hearth could be fused and run out of the tapping holes. This idea contributed materially to increasing the capacity of a blast furnace, and to decrease the number of furnaces that were needed in the United States from 1873 to 1876, to supply the decreasing demand.

Other ideas, introduced by the more progressive and the financially stronger furnace owners were fire-brick stoves, instead of the old iron stoves, by which the heat of the blast would be greatly increased, higher furnaces, larger hearths, higher pressures of blast, and greatly increased violence of blast, and the running of the furnace by noting the revolutions of the engine, and keeping the quantity of blast constant, instead of running with constant pressure. The durability of the lining of the furnace was increased by making thinner walls and cooling them by water jackets. In general all the equipment of the furnace was improved, the engines were made stronger and run faster, the boilers were increased in number, the methods of burning the gas were improved, and the hot blast ovens were enlarged.

The enormous development of the Convellsville coke industry, and the discovery that coke was a much better fuel than anthracite for making pig iron, together with the development of the Lake Superior iron mines, at the same time that the New Jersey and Pennsylvania mines showed signs of exhaustion, tended to move the center of the iron industry westward, and destroy the supremacy which had been held by the Lehigh Valley for many years.

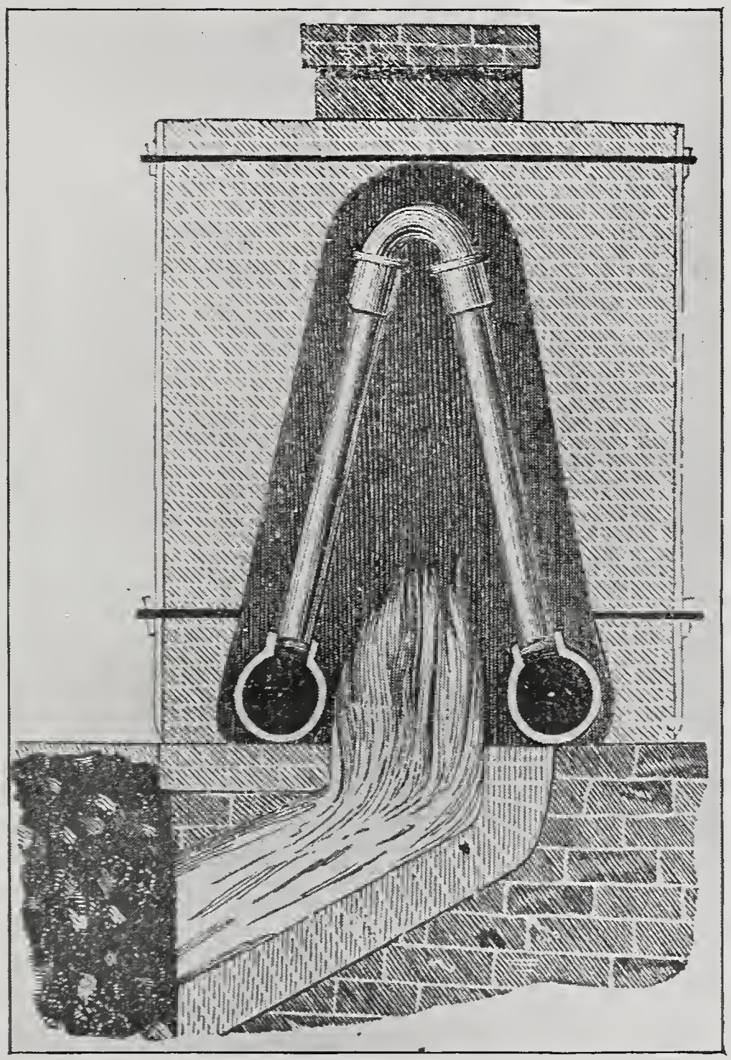


SECTION OF A BLAST FURNACE HEARTH THROUGH THE DAMSTONE.

In 1880 a new impetus was given to the rapid driving of blast furnaces by the discovery by Mr. Julian Kennedy, in his blowing of the A furnace of the Edgar Thompson steel works, that a furnace could be driven at a faster rate than had ever before been dreamed of. Mr. James Gayley, in his paper read before the British Iron and Steel Institute in 1890, says of the furnace: "The large outputs obtained from this furnace by the use of a large volume of air was a matter of common knowledge; the

practice of fast driving soon became the accepted one, and with our national ardor it was prosecuted enthusiastically. In every direction engines that had been running along for years at a methodical gait were oiled up and started off at a livelier pace; new boilers were added, the old hot blast stoves, not supplying sufficient heat, were torn down and replaced by the more efficient fire-brick stoves. At many works rapid driving degenerated into excessive driving."

first time exceeded the maximum figures reached in 1873, being 3,070,875 tons, and in 1880 it advanced to 4,295,414, and in 1882 to 5,178,122 tons, or more than double the figures of 1878. With all the increase in capacity of the furnaces, caused by rapid driving, more furnaces had to be put in blast to keep up with the extraordinary demand, so that the number of furnaces in blast at the end of 1881 was 455, the highest number that has ever been in blast,



HOT BLAST, HEATED ON THE TOP OF THE BLAST FURNACE.

But the furnace owners were stimulated to fast driving not only by the knowledge that furnaces could be driven fast, but also by the knowledge that they had to be driven fast on account of the exigencies of the market. The "boom" that began in the latter half of 1879 caught the furnaces unprepared for it, and the price of iron was more than doubled in six months, rising from $20¾ in July, '79, to $41 in January, 1880. In 1879 the production for the

against 265 furnaces at the end of 1878. But the increase of average capacity which began at such a rapid rate in 1880 has continued ever since, so that only 236 furnaces were in blast at the end of 1884, 4,589,613 tons having been produced in that year, and only 311 furnaces at the end of 1890, in which year 10,307,028 tons were produced.

The re-location and re-adjustment of the iron business was apparently postponed by the boom of 1879, for in 1880

every furnace that was anywhere near being in condition to go in blast was blown in, and for a time made a profit, but as soon as the boom in prices was over, and the increased capacity of the furnaces caught up to the demand, which took only about one year, prices fell below the profit point to more than 200 furnaces, and they were blown out, most of them never to be blown in again. The law of the survival of the fittest then began to operate in good earnest. The strongest companies, with good locations, ample capital, and long foresight, took advantage of the period of depression of 1884 and 1885 to tear down old furnaces and build larger ones, the coke producers enormously increased the number of their ovens, the Lake Superior ore men opened new mines, built new docks and new vessels for carrying the ore ; the whole country was explored for new regions in which to build blast furnaces ; the development of Alabama's resources was prosecuted with vigor, preparing that State to take the position she now holds, of the third largest producer in the Union ; and a good start was made towards the development of Virginia. So fast was this work of extension prosecuted, that the furnaces were amply able to take care of the enormous demand which took place in the next few years, and advanced the production from 4,529,869 tons in 1885 to 10,307,028 tons in 1890. The capacity increased so much faster than the demand that there was no more danger of a boom like that of 1879, and prices actually decreased in the face of an increasing demand. The furnaces that went out of blast on account of the decline in prices in 1884 have most of them remained out ever since.

The mortality of furnace companies has been still more remarkable than that of blast furnaces, for besides those that went out of existence on account of the abandonment of the blast furnaces, many others sold out to larger companies. No such thing as a trust has ever been formed by the blast furnaces, but consolidation of the business into the hands of large corporations has proceeded rapidly. In the Lehigh Valley one concern leased the furnaces of three other companies, and another leased five furnaces. In Chicago one steel company consolidated with two of its rivals, and now owns 17 furnaces with a producing capacity of 1,240,000 tons per year. In Alabama and Tennessee two large companies swallowed up several smaller rivals, and they have just amalgamated with each other making one concern with 17 furnaces, with an annual capacity of 633,000 tons. In the Hocking Valley, Ohio, in 1878 there were 13 blast furnaces with 12 owners, all of these furnaces having been built since 1874 to smelt native ores with the raw bituminous coal of the district. In 1892 there were 14 furnaces in the district owned by 7 companies, but not one of these companies is on the list of 1878, all of the original owners having sold out or become merged into the new companies. Many of these furnaces are now using Lake Superior ores and Connellsville or Virginia Coke, instead of the native raw materials.

In the anthracite region, comprising the territory east of the Susquehanna river, the changes have been the most severe. Nearly half of the charcoal furnaces in that region have permanently gone out of blast since 1878, and of the anthracite furnaces many have gone out permanently, others have been rebuilt, and many have changed owners. The following list of furnaces taken from Mr. Swank's directories of 1878 and 1892 show the principal changes that have taken place in that region. The furnaces are arranged in the order of the list of 1878, which was alphabetically arranged according to names of furnaces, which accounts for the names of many locations being repeated. The capacities are those given in the directories with the exception of a few estimates in 1892 made necessary by the different grouping of some of the furnaces in that year as compared with 1878.

The following tables give an idea of changes that have taken place in the location of the furnaces and in their productive capacities :

BLAST FURNACES LISTED IN 1878 AND IN 1892.
(In blast, or in condition to be blown in, when the state of the market permits.)

Location.	Number of Furnaces in 1878.	Year First one Built.	Annual Capacity Tons.	Number of Furnaces in 1892	Annual Capacity, Tons.	Number of Firms or Companies. 1878.	1892.
MAINE.							
Bangor	1	1846	6,000	1	6,000	1	1
VERMONT.							
Pitteford	1	1844	4,000	......	......	1	......
MASSACHUSETTS.							
W. Stockbridge	1 (Anth.)	1850	10,250	......	......	1	......
Berkshire Co	5	1765	17,500	4	19,500	3	2
CONNECTICUT.							
Litchfield Co	10	1825	36,500	9	41,500	8	7
Total N. England	18 17 Charcoal, 1 Anthracite.	......	74,250	14 (Ch.)	67,000	14	10
NEW YORK (Anthracite Furnaces.)							
Troy	2	1865 & 7	30,000	2	50,000	1	1
Troy (1886)	......	......	......	3	160,000	......	1
Port Henry	1	1872	18,000	1	26,000	1	1
Charlotte	1	1868	10,500	1	20,000	1	1
Kirkland	1	1873	6,000	1	18,000	1	1
Greenwood	1	1854	11,500	......	......	1	......
Cold Spring	1	1863	16,000	1	17,000	1	1
Hudson	1	1860	10,000	......	......	1	......
Crown Point	2	1873	36,000	2	45,000	1	1
Sylvan Lake	1	1873	7,000	......	......	1	......
Elmira	2	1872	30,000	2	36,000	1	1
Poughkeepsie	2	1860	25,000	2	30,000	1	1
Buffalo	1	1863	12,000	......	......	1	......
Ft. Edward	1	1853	11,000	......	......	0*	......
Franklin	2	1870	20,000	1	36,000	1	1
Hudson	2	1851	22,000	2	26,000	1	1
Albany	2	1871	25,000	......	......	1	......
New York	2	1851	17,000	......	......	1	......
Napanoch	1	1854	6,000	......	......	1	......
N. Tonawanda	1	1873	12,000	1 (Coke)	85,000	1	1
Albany	2	1873	28,000	2	30,000	1	1
Geddes	2	1870	28,000	2 (Coke)	36,000	1	1
Furnaceville	1	1870	6,000	......	......	1	......
Peekskill	1	1853	12,000	1	15,000	1	1
Hort Henry	2	1853	28,000	2	40,000	1	1
Poughkeepsie	2	1848	20,000	......	......	1	......
Sterling and Southfield	2	1806	10,000	2	16,000	1	1
Buffalo	3	1861	28,000	......	......	1	......
Buffalo (1891)	......	......	......	3 Coke Building.		......	1
Total	42	......	495,000	31 (6 Coke)	686,000	26	18

Charcoal Furnaces, in 1878, 16; Annual Capacity, 56,000 tons; Charcoal Furnaces, in 1892, 9; Annual Capacity 67,500 tons; Number of Firms or Companies, in 1878, 12; in 1892, 7.

* In the column headed Number of Companies, 0 means that the furnace is run by a company already taken account of, as owner of another furnace.

Location.	Number of Furnaces in 1878.	Year First one Built.	Annual Capacity. Tons.	Number of Furnaces in 1892.	Annual Capacity, Tons.	Number of Firms or Companies. 1878.	1892.
NEW JERSEY.							
Phillipsburg	3	1848	50,000	3	50,000	1	1
Boonton	2	1848	25,000	......	......	1	......
Franklin	1	1873	15,000	1	29,000	1	1
Hackettstown	1	1874	10,000	1	15,000	1	1
Chester	1	1878	8,000	......	......	1	......
Stanhope	2	1864	40,000	2	56,000	1	1
Newark (Spiegel)	3	1855	6,000	2	7,500	1	1
Oxford	3	1742	25,000	1	18,000	2	1
Port Oram	1	1868	11,000	1	25,000	1	1
Ringwood	2	......	5,000	1	Idle many yrs	1	1
Seacucus	1	1877	15,000	1	30,000	1	1
Hudson Co. (Spiegel)	......	......	......	1	6,000		1
Pequet (1884)	......	......	......	1	27,000	......	0
Total	20	......	210,000	15	268,500	12	10
PENNSYLVANIA.							
Lehigh Region.							
Allentown	5	1846	60,000	2	50,000	1	1
Allentown	2	1864	20,000	2	24,000	1	1
Bethlehem	6	1863	76,800	5	150,000	1	1
Pairyville	3	1855	30,000	3	35,000	1	1
Redington	2	1869	26,800	2	45,000	1	1
Catasauqua	6	1840	70,000	4	150,000	1	1
Riegelsville	1	1848	20,000	1	43,000	1	1
Emaus	1	1872	10,000	1	32,000	1	0
Glendon	5	1843	60,000	4	100,000	1	1
Easton	1	1876	12,000	1	20,000	1	0
Allentown	2	1869	21,000	2	41,000	1	1
Coplay	3	1853	30,000	3	55,000	1	1
Alburtes	2	1867	25,000	2	30,000	1	0
Macungu	1	1874	10,500	1	17,000	1	0
Bethlehem	1	1873	11,200	1	20,000	0	0
Bethlehem (Spiegel)	......	......	......	1	3,000	......	1
Bingen	1	1870	10,000	1	15,000	1	0
Hellerton	2	1868	25,000	2	30,000	1	0
Holsendaugua	6	1855	94,000	6	140,000	1	1
Glendon	1	1872	7,500	1	15,000	1	0
Total	51	......	619,800	45*	995,000	18	12
Schuylkill Valley.							
Pottstown	1	1867	12,000	1	45,000	1	1
Bechtelsville	1	1875	11,500	1	19,000	1	1
Lyons	2	1874	16,000	......	......	0	......
Edgehill	1	1872	12,000	1	28,000	1	1
Reading	2	1844	16,000	2	30,000	1	1
Budsboro	4	1846	30,000	3	70,000	1	1
Reading	2	1869	20,500	2	45,000	1	1
Kutztown	1	1875	10,000	......	......	0	......
Leeport	1	1852	12,000	1	18,000	1	1
W. Conshohocken	2	1847	20,000	1	20,000	1	1
Minersville	1	1872	10,000	......	......	1	......
Monocacy	1	1854	10,000	......	......	1	......
Port Kennedy	1	1854	9,000	1	30,000	1	1
Moselem	1	1823	10,400	1	8,000	1	1

* 11 of these 45 furnaces leased to two companies.

Location.	Number of Furnaces in 1878.	Year First one Built.	Annual Capacity Tons.	Number of Furnaces in 1892.	Annual Capacity Tons.	Number of Firms or Companies. 1878.	1892.
PENNA.—(Con'd)...........							
Schuylkill Valley.							
Temple	1	1836	5,000	1	10,000	1	1
Norristown	1	1869	10,000	2	46,000	1	1
Philadelphia	1	1873	10,000	....	....	1	....
Phoenixville	3	1845	25,000	3	45,000	1	1
Pottsville	3	1853	25,000	2	32,000	1	1
Conshohocken	2	1845	19,000	....	....	1	....
Port Carbon	1	1872	8,000	1	10,000	0	0
Reading	2	1854	20,000	2	40,000	1	0
New Ringgold	1	1873	7,000	1	15,000	1	0
Robesonia	2	1845	16,000	1	50,000	1	1
Sheridan	2	1867	18,000	2	62,000	1	1
St. Clair	1	1845	9,000	....	....	0	....
Swedeland	2	1850	20,000	2	88,000	0	1
Temple	1	1867	8,000	1	27,000	1	1
Topton	1	1873	9,000	1	27,000	1	1
Warwick	1	1875	17,000	1	44,000	1	1
Wm. Penn	3	1844	20,000	....	....	1	....
Thurlow (1881)	....	....	....	1	40,000	....	1
Total	49	... .	415,400	35*	849,000	26	21
Upper Susquehanna Anthracite.							
Bloomsburg, ...	1	1854	9,000	1	14,500	1	1
Chulasky	1	1846	8,000	1	6,500	1	1
Danville	2	1840	13,750	2	15,200	1	1
Danville	2	1867	14,000	2	40,000	1	1
Duncannon	1	1852	8,000	1	20,000	1	1
Glamorgan	2	1868	12,000	....	....	1	....
Bloomsburg	2	1844	12,000	2	18,000	1	1
Scranton	5	1849	80,000	5	125,000	1	1
Minersville	1	1874	6,000	....	....	1	....
Mansfield	1	1854	6,000	....	....	1	....
Newport	1	1872	7,000	....	....	1	....
Mt. Union	1	1837	3,500	....	....	1	.... ..
Northumberland	1	1873	8,000	....	....	1	....
Danville	3	1842	18,000	2	38,000	0	1
Winfield	1	1854	7,000	1	7,000	1	1
Total	25	....	132,250	17	284,200	14	9
Lower Susquehanna Anthracite.							
Wrightsville	1	1867	6,000	1	25,000	1	1
Middletown	1	1853	7,000	1	8,000	1	1
Columbia	3	1845	18,000	2	45,000	1	1
Chickies	2	1845	12,100	2	37,000	1	1
Cornwall	5	1850	40,000	5	110,000	1	1
Lancaster	1	1846	6,000	1	6,500	1	1
Dauphin	1	1854	5,000	....	....	1	....
Harrisburg	1	1873	5,000	1	20,000	1	0
Marietta	1	1848	6,500	....	....	1	....
Harrisburg	1	1844	6,000	....	....	1	....
Columbia	1	1848	6,500	....	....	1	....
Lebanon	2	1846	20,000	2	70,000	1	1
Lebanon	1	1867	6,000	1	22,000	1	1

* Of the 35 furnaces in 1892, 5 are idle and for sale.

Location.	Number of Furnaces in 1878.	Year First one Built.	Annual Capacity Tons.	Number of Furnaces in 1892.	Annual Capacity Tons.	Number of Firms or Companies. 1878.	1892.
PENNA.—(Con'd)							
Lower Susquehanna Anthracite.							
Lebanon (1881)	....	....	....	2	70,000	....	1
Harrisburg	1	1873	7,500	....	....	1	....
Marietta	2	1847	10,000	....	....	2	....
Middletown	1	1883	5,000	1	9,000	1	1
Marietta	1	1868	6,000	1	19,000	1	1
Harrisburg	2	1855	20,000	2	40,000	1	1
Steelton	2	1872	30,000	4	175,000	1	1
Richmond	1	1865	3,000	....	....	1	....
Safe Harbor	1	1848	8,000	....	....	1	....
Pine Grove	1	1825	5,200	....	....	1	....
Columbia	2	1853	12,000	1	17,000	1	1
Union Deposit	1	1854	5,000	1	8,000	1	0
Harrisburg	1	1867	9,000	....	....	1	....
Boiling Springs (1881)	....	....	....	1	14,000	....	1
Colebrook (1885)	....	....	....	1	6,700	....	1
Cordelia	1	1848	?	1	9,000	1	1
Total	38	....	245,800	31	709,700	28	17

Charcoal Furnaces in Penna., 1878, 37; Annual Capacity, about 70,000 tons; Number of Charcoal Furnaces in 1892, 15; Annual Capacity, 61,700 tons; Number of Firms or Companies in 1878, 34; in 1892, 15.

PRODUCTION OF PIG-IRON IN PRINCIPAL DISTRICTS 1872 TO 1891, IN THOUSANDS OF TONS OF 2000 POUNDS EACH.

Year	Total U.S.	Pennsylvania.	Lehigh Valley, Pa.	Allegheny Co., Pa.	New York and N. J.	Ohio.	Illinois.	Mich. and Wis.	Alabama.	Md., Va., W. Va., Ky., Tenn., Ga.
1872	2855	1411	450	111	395	400	79	165	13	228
1873	2868	1390	390	159	399	406	56	198	22	227
1874	2689	1213	317	144	417	425	38	187	33	180
1875	2267	961	280	132	330	416	50	177	25	187
1876	2093	1010	261	129	206	403	54	146	25	144
1877	2315	1153	335	142	283	400	61	104	41	171
1878	2577	1342	417	217	319	421	78	121	41	187
1879	3071	1607	456	267	336	448	78	191	50	238
1880	4295	2083	545	301	565	674	151	251	77	318
1881	4642	2191	560	385	531	711	252	289	98	370
1882	5178	2449	609	359	593	699	360	296	113	462
1883	5146	2639	576	593	471	680	238	225	172	518
1884	4590	2385	432	487	322	567	328	226	190	464
1885	4529	2445	474	586	234	554	328	168	227	482
1886	6365	3293	666	737	392	908	506	257	283	586
1887	7187	3685	723	898	469	976	565	349	293	628
1888	7268	3589	559	891	359	1104	579	329	449	674
1889	8516	4181	577	1293	423	1216	601	373	791	768
1890	10307	4945	816	1498	547	1389	785	505	915	1024
1891	9273	4427	641	1636	456	1159	750	460	891	999

BLAST FURNACES IN THE UNITED STATES IN 1878 AND 1892.

State.	Number of companies or owners.		Number of furnaces.		Annual capacity.	
	1878.	1892.	1878.	1892.	1878. Net tons.	1892. Net tons.
Maine	1	1	1	1	6000	6000
Vermont	1	....	1	....	4000	....
Massachusetts	4	2	6	4	25,500	19,500
Connecticut	8	7	10	9	35,000	41,500
New York	37	25	58	37	536,000	753,500
New Jersey	11	9	19	15	204,000	274,345
Pennsylvania	162	113	275	219	2,597,000	6,662,748
Maryland	18	6	24	13	95,000	463,200
Virginia	29	31	33	33	74,900	677,000
West Virginia	11	4	11	4	100,000	184,000
North Carolina	5	1	7	1	11,000	6000
Georgia	9	6	11	6	43,000	107,000
Alabama	11	32	12	53	78,500	1,618,000
Kentucky	18	7	22	10	129,000	280,000
Tennessee	20	12	22	19	102,500	448,000
Ohio	82	50	103	72	948,000	2,176,000
Indiana	6	2	7	2	59,000	30,000
Illinois	7	4	12	20	262,500	1,365,000
Michigan	21	20	26	23	225,000	436,000
Wisconsin	10	10	15	10	117,000	293,500
Minnesota	....	1	....	1	....	50,000
Missouri	13	6	18	8	211,000	222,000
Texas	1	4	1	4	1,500	58,000
Colorado	....	1	....	3	....	100,000
Utah	2	....	3	....	8,500	....
Oregon	1	1	1	1	4,000	15,000
Washington	....	1	....	1	....	10,000
Total	488	356	698	569	5,868,000	16,296,000

Average capacity per furnace, 1878, 8407 net tons; 1892, 28,640 net tons.
Ratio of total capacity, 1878 to 1892, 1 to 2.78. Increase, 178 per cent.
Ratio of capacity per furnace, 1878 to 1892, 1 to 3.41. Increase, 241 per cent.
Decrease in number of furnaces, 129 = 18.5 per cent.
Decrease in number of companies, 132 = 27.0 per cent.

FURNACES IN BLAST 1873 TO 1891 INCLUSIVE, WITH PRODUCTION OF PIG-IRON.

Year.	Number furnaces in blast at end of year.	Total production of pig iron during the year. Net tons.	Average product per furnace. Net tons.	Kinds of pig iron.		
				Anthracite and mixed anthracite and coke. Tons.	Charcoal. Tons.	Coke and raw bituminous. Tons.
1873	410	2,868,278	6997	1313	578	978
1874	365	2,689,413	7367	1202	577	911
1875	293	2,266,581	7667	908	411	948
1876	236	2,093,236	8870	795	309	990
1877	270	2,314,585	8565	935	318	1062
1878	265	2,577,361	9726	1093	294	1191
1879	388	3,070,875	7915	1273	359	1439
1880	446	4,295,414	9631	1808	538	1950
1881	455	4,641,564	10,201	1734	639	2268
1882	417	5,178,122	12,418	2042	698	2438
1883	307	5,146,972	16,765	1886	572	2690
1884	236	4,589,613	19,829	1586	458	2545
1885	276	4,529,869	16,413	1474	400	2676
1886	331	6,365,328	19,225	2100	460	3806
1887	339	7,187,206	21,201	2338	578	4271
1888	332	7,268,507	21,893	1926	599	4744
1889	344	8,516,079	24,756	1920	644	5951
1890	311	10,307,028	33,141	2449	704	7155
1891	313	9,273,455	29,628	2090	646	6537

The production being that of the whole year, while the number of furnaces given are those in blast at the end of the year, the figures in the last column do not accurately show the average production of the average number of furnaces that were in blast during the whole year. In 1891 a great increase in the demand during the last four months of the year caused a number of furnaces to be put in blast, so that more furnaces were in blast at the end of the year than the average for the year. This causes the apparent reduction in the average capacity per furnace in 1891, as compared with 1890, from 33,141 to 29,628 tons. The average number of furnaces in blast during the year, according to the monthly returns published in the *Iron Age*, was only 280, which would make the average capacity per furnace 33,119 tons, or about the same as in 1880. The apparent reduction in the average capacity, per furnace, in the years 1879 and 1885 is accounted for in the same way. The great "boom" in iron took place in the latter half of 1878, so that at the end of the year there were many more furnaces in blast than the average for the year; and in the latter part of 1885 there was a recovery from the depression following the financial troubles of 1884, which recovery also caused a number of furnaces to be blown-in. The plotted diagram made from the figures in the above table shows clearly the relation of the furnaces in blast to the total product.

From 1873 to 1876 the total production of iron decreasing, while the product per furnace slightly increased, there was a great decrease in the number of furnaces in blast, or from 410 to 236. The increased demand for iron after 1876 caused a steady increase in the number of furnaces in blast until 1882, when the great increase in capacity, per furnace, which began in 1879, became felt, and in 1882 and 1883 the number of furnaces in blast decreased rapidly in spite of the increased demand for iron. The depression in 1884 and 1885, and the reaction in 1886, both had their proper effect, the first decreasing and the second increasing the number of furnaces in blast; but from 1886 to the present time, in spite of an extraordinary increase in the demand for pig iron, so great has been the increase in the average capacity of the furnaces that the number of furnaces in blast has remained practically constant.

The changes in the location and in the capacity of the furnaces are by no means complete. The 569 furnaces now on the active list have an average annual capacity of 28,640 tons each and a total capacity if they were all in blast of 50 per cent more than the present demand. As the new furnaces recently built for using Lake Superior ores have a capacity of not far from 100,000 tons each, and the new furnaces in the South have a capacity of nearly 50,000 tons each, it is evident that a much smaller number of furnaces than 569 will supply the demands for pig-iron for many years to come, and it is to be expected that many of the smaller furnaces now on the active list will be abandoned within a few years. The decrease in the number of companies or owners, 27 per cent. in 14 years, is a remarkable fact in the economic history of the age. It is characteristic of the change from individual to corporate ownership which is going on in nearly all important industries. While the nominal ownership, however, is being concentrated into a few corporations, the actual ownership is probably however, through the distribution of stock in these companies among the general public, in a greater number of hands than ever before.

Profit sharing, and investment by the profit-sharing workmen of their earnings in stock of the companies also tends to distribute the ownership, and in some measure to solve the labor problem. Thus the history of the changes in the iron industry should be no less instructive to the political economist than they are to the engineer.

DIRECT CONNECTED ENGINES.—I.

EVERY square foot of ground space that can be dispensed with in the erection of the large electric light and power central stations materially reduces the necessary investment of the company operating the same.

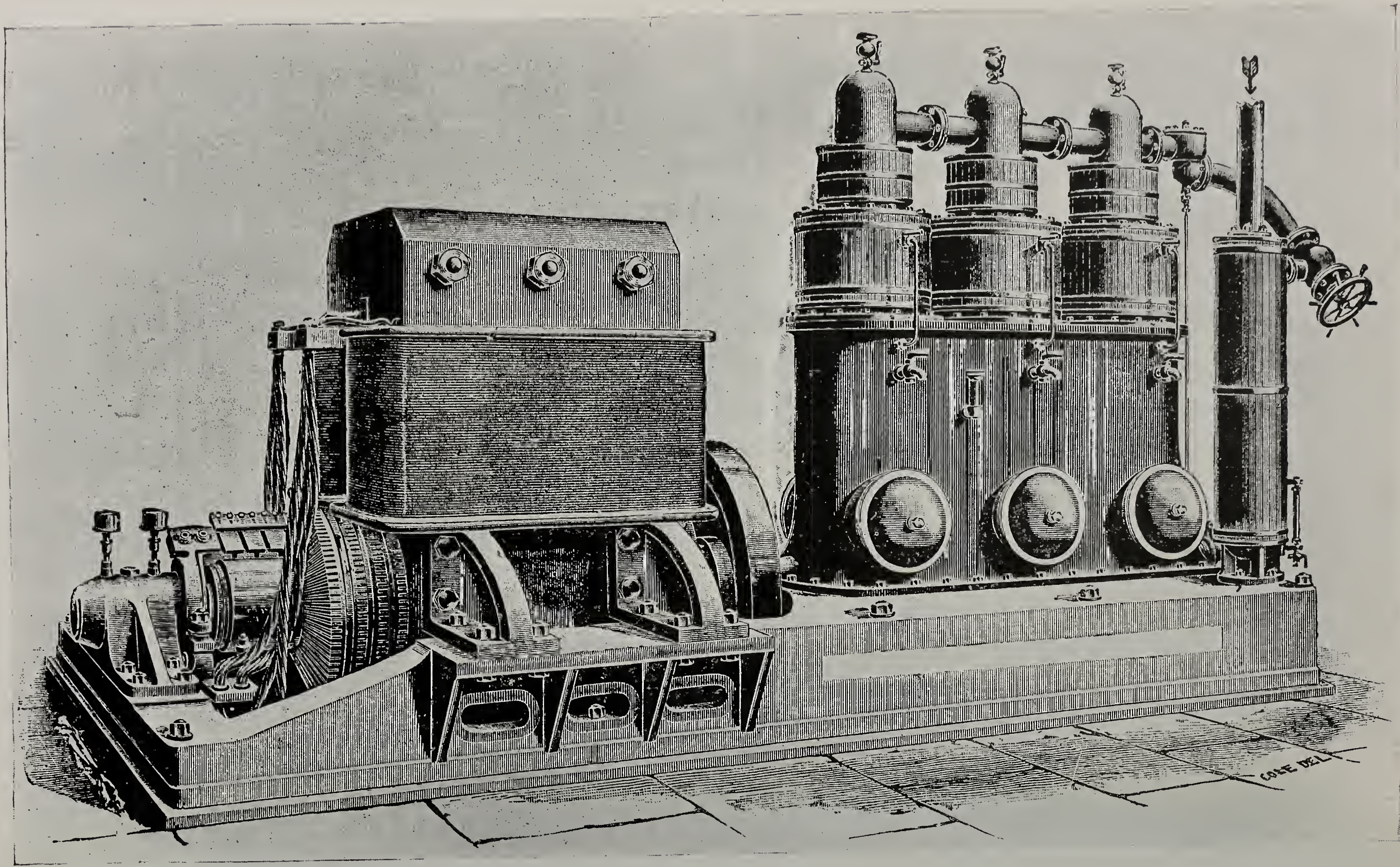
As our cities are growing up and the cost of land approaches such enormous figures, there is a steadily increasing demand for economy in this direction. This is probably the most serious problem that to-day confronts the management of the electric light and power companies in large communities.

The same need of saving floor space is also felt in many other cases where steam is used, although not to such a large extent as in the electrical interests. Every transformation or transmission of energy is a loss of money, and it follows that, when the crank-shaft of the engine is the armature shaft of the dynamo, the loss is reduced to its lowest terms. The normal resistance of an armature is strictly torsional, and the difference can be quickly appreciated between the power required to drive it when spinning it by the end, against that required to drive it under the transverse strain of a heavy belt. The power wasted in transmission is an uncertain factor, but even in the simplest method, that of belting direct from the engine to the dynamo, the loss can scarcely fall below 2 per cent., and it has been measured as high as 10. Where countershafting is employed the frictional loss is again doubled by being repeated at the receiving and delivering bearings of the countershafting. If the engine-shaft, or still worse, the countershaft, is out of line, the frictional load may run up to any figure, limited only by the preservation of the bearings. With the direct connected dynamo the frictional load due to these causes entirely disappears, leaving nothing but the internal friction of the engine to be accounted for. In the item of attendance and maintenance the coupled generator possesses manifest advantages in eliminating the belt account wholly, and the oil and babbitt account in large part. The absence of the noise, which is inseparable from the use of belting, is also a desirable feature, and more particularly in stations centrally located in business and residence districts.

The difficulties surrounding the building of electric generators in large sizes, at speeds below 100 revolutions per minute, are of a formidable nature, while the construction of such machines to run at speeds of 200 to 300 presents practically no difficulties. Small generators may be driven in the customary manner, but when units of 300 to 1000 horse-power or more are driven, the mechanical difficulties and losses are unduly augmented as size increases, and direct connection appears not only a necessity, but a welcome one. The earlier attempts in direct connection were more or less unfortunate, the failures being due largely to the apparent necessity of high speed in the dynamos and the inability of existing steam engines to meet their requirements.

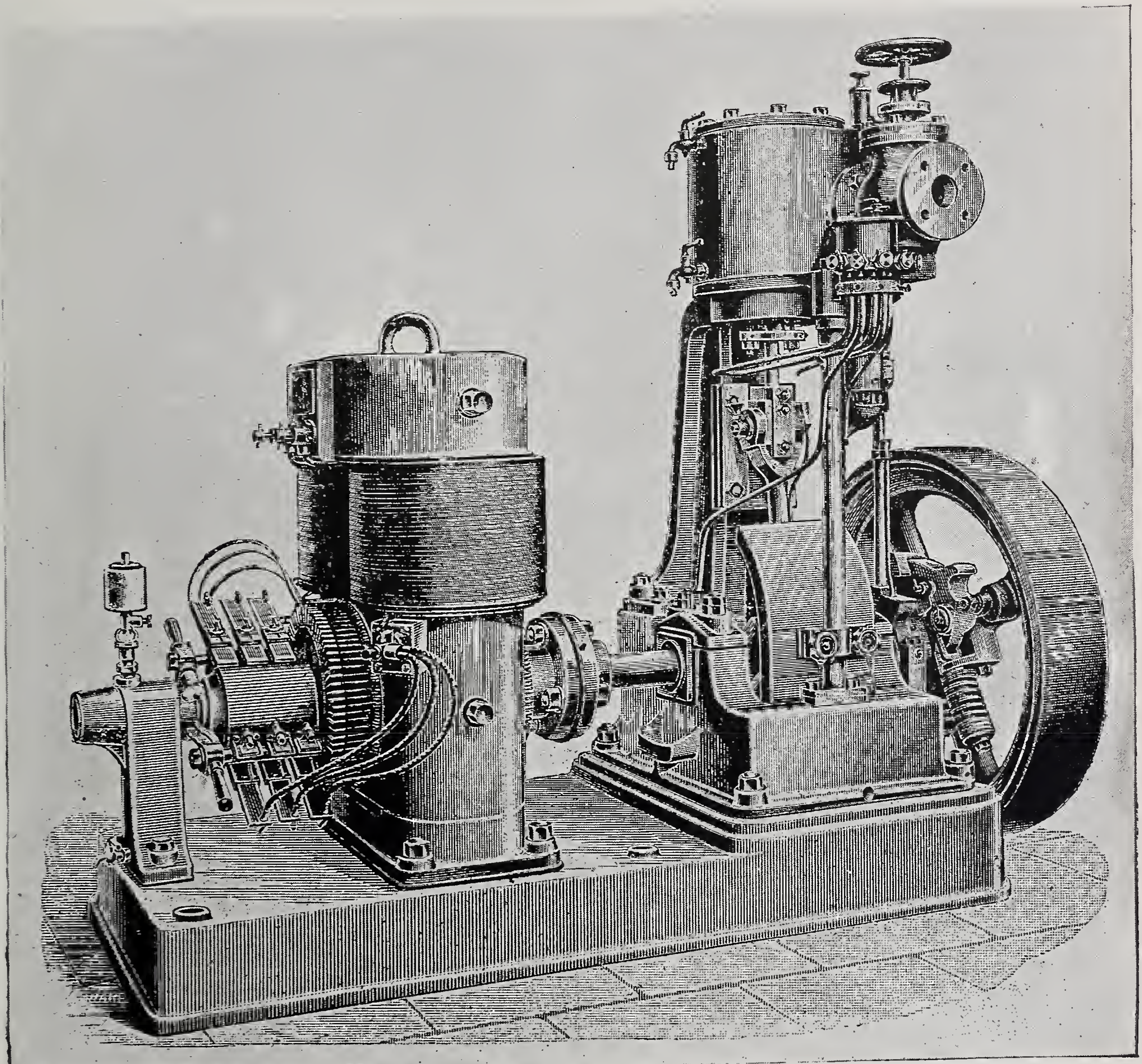
European practice is doubtless ahead of us in regard to coupling large dynamos direct to the engine. It is doubtful, however, if the responsibility really rests on the American engineers. The assignable cause is probably commercial. A very noticeable feature of the late Frankfort Electrical Exhibition was that all large machines were multipolar and direct coupled ; large bipolar machines apparently do not exist in Germany. But European capital, contenting itself with smaller and slower gains, is willing to make the disproportionate investment required by the comparatively slow speeds which are alone possible to the forms of construction there adopted. In America we must have faster running machinery, more compact in form and of a greater earning capacity per dollar of cost.

The use of dynamos driven directly by high-speed engines is so universal in

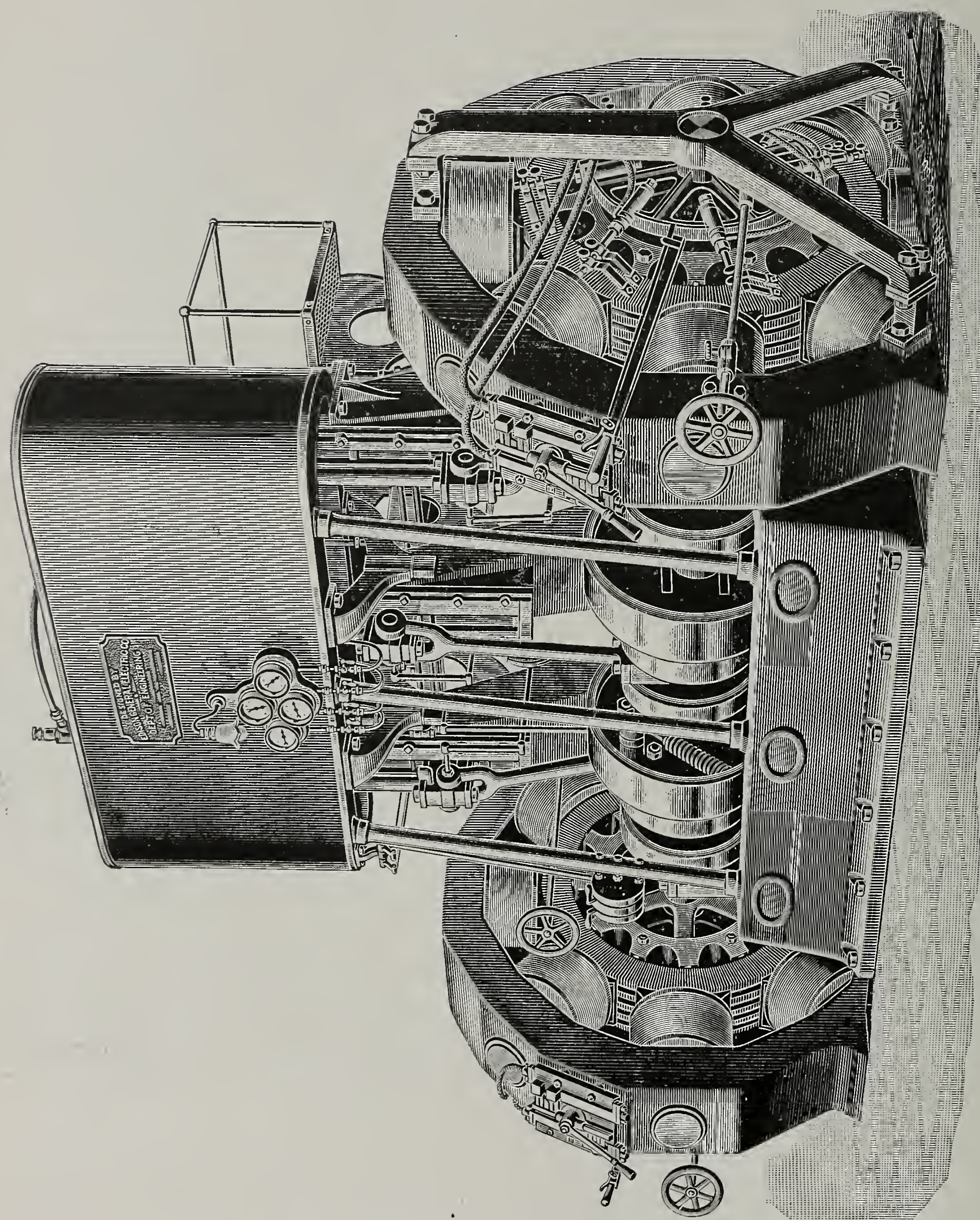


WILLANS AND SIEMENS SET.

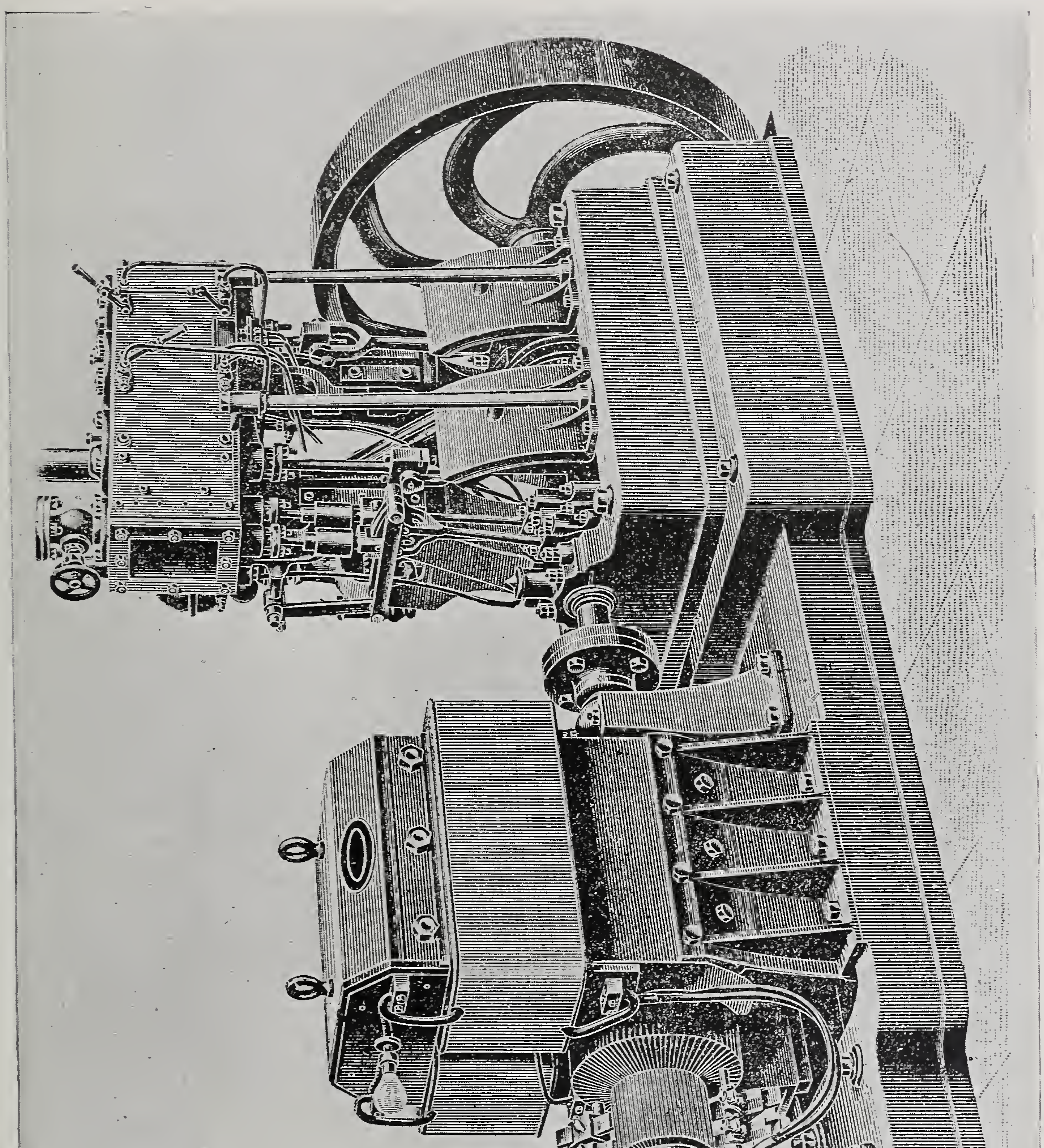
England as to be considered representative of English practice. Taking the plants now at work in central stations in the United Kingdom which have 300 horse-power and upward in position, the total horse-power now in use, according to the *Electrical Review*, is about 33,000. Of this, 22,300, or about 68 per cent. of the whole, consists of engines of the Willans type driving various kinds of dynamos coupled direct to them. Of the remainder, we find about 4800 horse-power, or 14 per cent. in the Deptford station, which can hardly in its present condition be called a representative one; about 2600 horse-power, or 8 per cent., in the Sardinia street station of the Metropolitan Supply Company, which is of American design; about 500 horse-power, say 1½ per cent., in the shape of Parsons turbo-generators at Newcastle, and in the remaining stations about 300 horse-power we find a total of above 2800 horse-power, which is 8½ per cent. of the whole. These last-named stations are all of them situated in places where engine-room space is not valuable, so that it is safe to say that the horse-power installed in Great Britain, following the so-called English practice, is five times as great as any other arrangement.



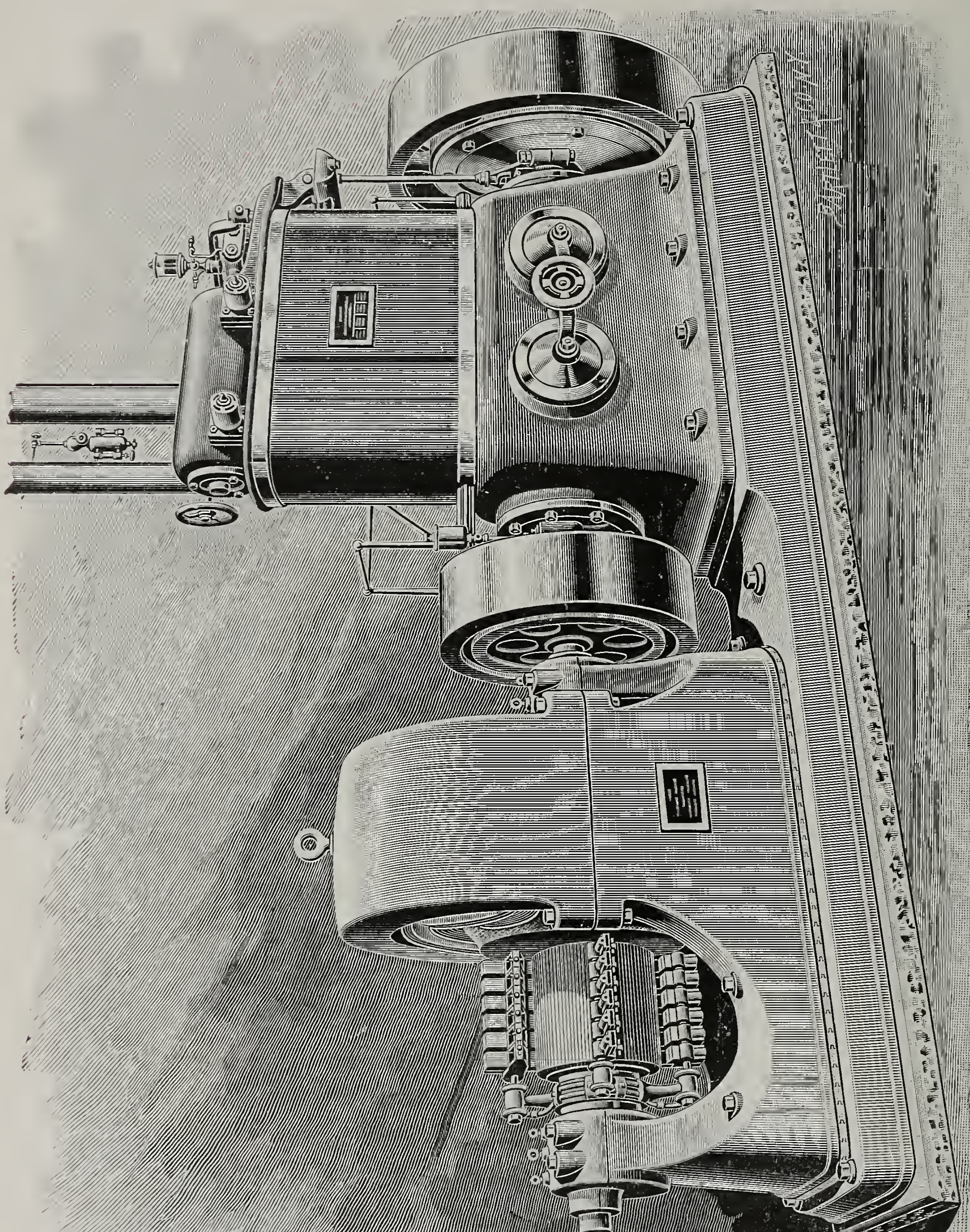
HOLMES DYNAMO.



EDISON TRIPLE EXPANSION ENGINE AND DYNAMOS.



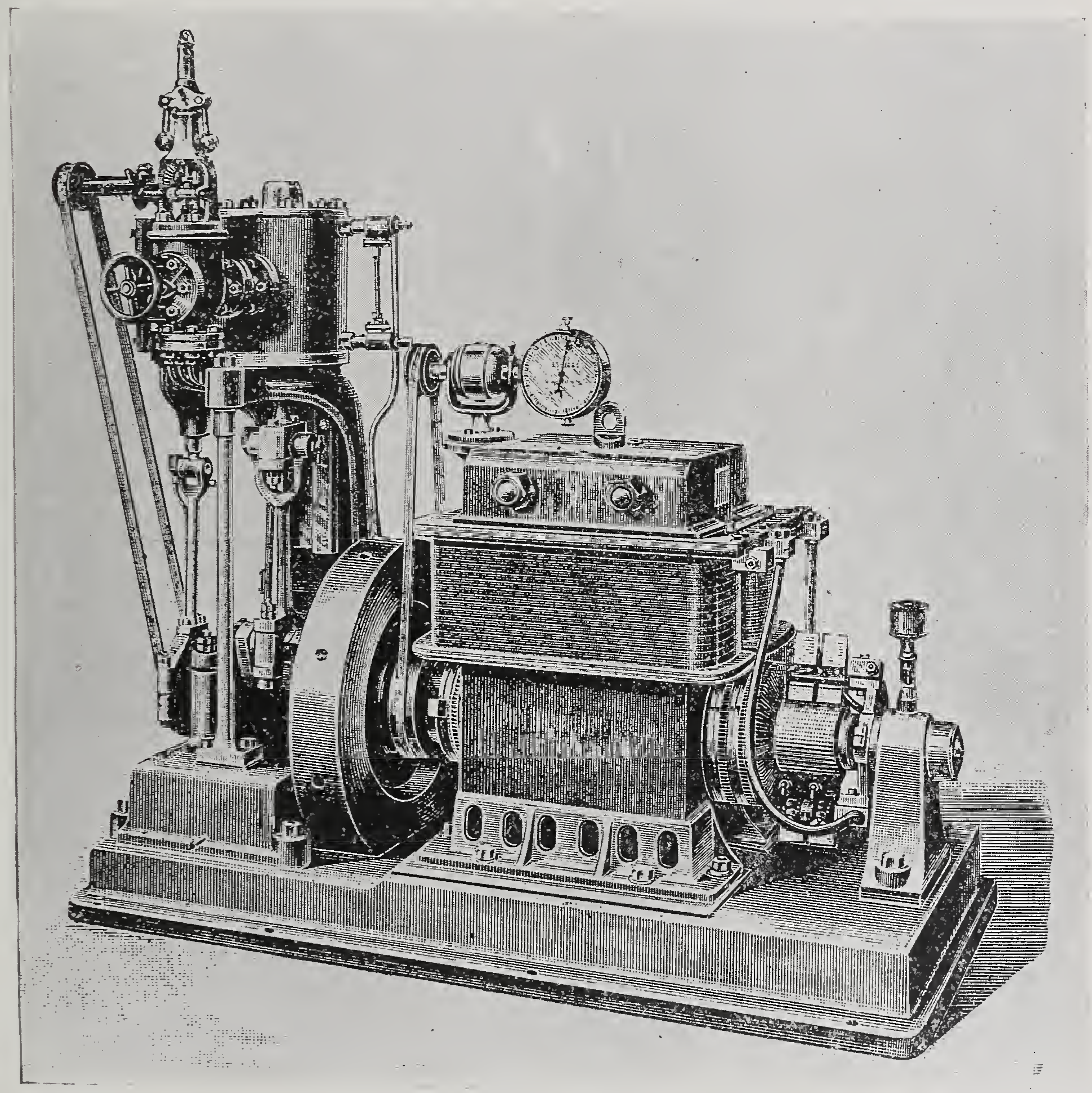
RONALD A. SCOTT'S DYNAMO.



WESTINGHOUSE ENGINE AND DYNAMO.

63,933

In 1880, the Brush Electric Company conceived the application of the electric arc for locomotive head-lights, and laid the problem of a direct coupled engine before Mr. H. H. Westinghouse for solution. The terms of the problem were about as follows : The speed must not be less than 1000 revolutions, and the power developed not less than 1½ net horse-power. The engine must operate under 140 to 180 pounds of steam ; it must be self-contained, so as to be bolted to the locomotive, like a brake-pump ; it must be sufficiently rigid, so as to stand all the shock and jar of service ; it must be protected from dust and cinders, and must be so designed as to enable it to run for an indefinite time without any attention, while the locomotive is side-tracked and the engineer absent. The outcome of this problem was the production of the single-acting, self-contained and self-lubricated Westinghouse engine. These are the circumstances which led to the building of the first direct connected dynamos in the United States, if not in the world.



FOR SHIP LIGHTING.

A new multipolar generator coupled

direct to a compound engine and designed to run at 250 revolutions, has recently been introduced by Westinghouse, Church, Kerr & Co. The generator is thoroughly insulated from the common bedplate by a sheeting of tarred plank, the bolts being insulated by bushings and washers of non-conducting material. The insulation is completed at the coupling, in which non-conducting material is interposed to prevent metallic contact, so that there can be no trouble from grounds. The coupling is one of the principal features of this combined plant. It is made in the form of a fly-wheel and contains a case in which are placed some springs to form the connection between the engine and dynamo. The fly-wheel and case are divided in the center, and the generator shaft is fastened to one part and the engine shaft to the other. The springs connecting these parts are six in number, so arranged as to bring three in tension and the other three in compression, when the machine is in operation.

The construction of the coupling is such as to permit a movement at the rim of about 2 inches, the radius being 18 inches. This is equivalent to a belt stretch of 8 inches on a fly-wheel of average size, and is entirely capable of gradually taking up any sudden change of load.

The Edison Company has brought out a new line of central station units, consisting of two multipolar dynamos coupled direct, one on either side, to a triple-expansion engine, and ranging in capacity from 100 to 1000 indicated horse-power. The increased diameter of the armature in the multipolar type of machine gives a very large heat-radiating surface. It is claimed that this point, in connection with a few special features, allows the Edison generators to maintain heavy loads for periods of any duration. The armatures are mounted directly on both ends of the crank-shaft, and are expected to act as the fly-wheels of the engine. The engine is of the triple-expansion, three-crank, inverted cylinder, automatic condensing type. The crank-shaft is of forged steel, fitted with cast-iron balanced discs, to which the crank-pins are fitted. There are two bearings to each crank and an additional large bearing on each end of the shaft to carry the armature. On the shaft are three eccentrics, each operated by its own independent governor, so that the point of cut-off in each cylinder is changed equally with the load. In this manner the tendency to race is avoided, should the total load at any time be thrown off or any accident happen. The engines are calculated for the maximum efficiency point at about 12½ per cent. below the normal maximum capacity of the generator, and have a range to a maximum capacity of 20 per cent. above the normal maximum output of the generator at 160 pounds initial pressure and vacuum of 24 inches. This permits each engine, in case of an accident to the condensing apparatus, to operate the generator satisfactorily non-condensing.

Several English builders use the two-pole upright type of dynamo for coupled plants, although it is not the type they employ for belt-driven dynamos. This type has many advantages. The pull on the iron of the armature coil, due to the want of magnetic balance, tends to lift it, and therefore relieves the weight on the bearings. The center of rotation is low, and this fact simplifies the arrangement of pedestals, etc. It also gives a special advantage for coupling direct to engines, as there is no need to pack the engine up on a high bedplate. This saves valuable space in ship-lighting plants by reducing the height. The chief disadvantage of this type is that it is not always easy to prevent magnetic leakage through to the bed-plate. At the recent Crystal Palace Electrical Exhibition there were presented a number of dynamos of this upright type coupled direct to the engines. Upon other pages will be found illustrations, taken from the *Electrical Engineer* (London), of the plants of this kind exhibited by Holmes & Co., Ronald Scott & Co., and Siemens Bros. & Co. The engine shown by the last-named firm was one of Willans & Robinson's high-speed. It had three cranks at 120 degrees apart, three low-pressure cylinders 20 inches in diameter, three high-pressure cylinders 14 inches in diameter, and a 9-inch stroke. The standard speed was 350 revolutions. The dynamo had a capac-

ity of 1500 ampères at 120 volts. The magnet limbs and yoke piece were construced out of solid forgings of wrought-iron, supported by gun-metal brackets bolted to the cast-iron combination frame, allowing sufficient space between the frame and magnet to prevent as much as possible any magnetic leakage. Messrs. Siemens Bros. also exhibited a ship-lighting plant of which an illustration is presented herewith. This plant consisted of a Tangye compound vertical engine, coupled with the usual ship dynamo, and estimated to give 40 actual horse-power at 200 revolutions with 90 pounds of steam. The weight of this combined plant was a little under 7 tons.

A combined engine and dynamo plant is constructed by Ernest Scott & Mountain, Limited, which is especially designed to conform to Admiralty requirements for use on board war ships or other places where space is limited. The engines for all sizes of plant, with the exception of the smallest, are of the compound type, and are constructed for a working pressure of 160 to 200 pounds; but they are capable of giving the full normal output at a pressure of 100 pounds. The cylinders are of cast-iron, lapped with steel. Steam is admitted to both cylinders by a double piston-valve placed between the two cylinders and worked by one eccentric and rod from the crank-shaft.

(To be continued in July issue.)

ABOUT DAMPER REGULATORS.

EDITOR OF CASSIER'S MAGAZINE:

We notice on page 65 of your last issue that Mr. Stillman comes out with his usual offer of $2000 (addressed to the universe) for a regulator as good as the Spencer.

Will you please inform the readers of your magazine if this is a *bona fide* offer to be given to any party who can show that there is a better regulator than the Spencer? We desire that this be done as early as possible, as there are many of your readers who are interested in this matter. Please insert in your next issue a card stating that Locke Bros., of Salem, Mass., have accepted the challenge thrown out by G. G. Stillman, of Boston, offering $2000 for a regulator as good as the Spencer, the trial to be made under your direction, as may be hereafter arranged. You will, therefore, inform Mr. Stillman that he must either withdraw his offer or meet this trial, or if it does not mean what it purports to be, that the wording in his advertisement must be so changed as to express what he does mean. He well knows that he cannot compete with the Locke regulator, and would stand no chance in such a trial, and we believe his whole talk is a "bluff;" and we propose to place him just where he belongs, with a machine which we are able to show is only third-rate. We shall be pleased to hear from you upon this subject, and think that we can make it interesting for your readers if we can get Mr. Stillman to "come to time."

Very respectfully,

LOCKE BROTHERS.

SALEM, MASS., May 19, 1892.

A PRACTICAL CONSIDERATION OF COMPRESSED AIR.*

By Wm. L. Saunders, C.E.

IN an address recently delivered before this Institute and published in the *Journal* for July, 1891, Dr. Coleman Sellers, in referring to the utilization of the power at Niagara Falls, used the following words :

"You may wonder why compressed air is thought of at all for transmission, as you have known in America that it has been thought to be a very wasteful manner of transmitting power, but the recent improvements that have been made in compressors have very much changed the condition of that mode of transmission, and the fact that so much gain is possible by reheating the air indicates a cheap power which can be transmitted long distances with economy."

This concise and truthful statement has been selected as a text for what I have to say on the subject of compressed air, because, in the first place, it calls attention to the very general impression which exists in America as to the "very wasteful manner" by which power is transmitted by compressed air, and it suggests the true solution of the problem, which is in the direction of improvements in air-compressors and reheating the air.

Compressed air, though one of the oldest of the sciences, is in its development and use one of the youngest. Hero, of Alexandria, a century before Christ, experimented and wrote upon "Pneumatics," calling special attention to the influence of heat in expanding and contracting air, and Professor Thurston has given us an account of an invention which was put into practical use by Hero, by which the opening and closing of temple doors was effected by the alternate rarefaction and condensation of air which was brought in contact with heated and cooled surfaces of altar tops. Yet the science of pneumatics played no important part in industrial progress until scarcely more than a century ago it came into general use for diving-bells, and later on it was applied by Brunel to caisson work.

The use of compressed air in America has been confined almost exclusively to mining, tunneling, bridge-building, and work in a confined space for which no other power was available. The question has not been one of economy of power, but of durability of apparatus, low first cost, light weight, economy of space, and general availability for the purpose. Dry, pure air delivered at a sufficient pressure by a machine which could be depended upon, has been the controlling consideration. Such a condition of things offers no stimulus in the line of fuel economy, and it is only during recent years and since the use of compressed air has been extended to work above ground, that the percentage of power delivered in proportion to that consumed has been recognized as a thing of great importance in the science.

Since the necessity of economy in the production and use of compressed-air-power became recognized, the question has been considered and the science developed by two distinct classes of men, —the theorists and the practical men. The theorists are the professors and engineers whose skill as mathematicians has enabled them to indulge in such an array of figures, and to produce so many cobwebs in diagrams relating to the expansion and contraction of gases, and bearing upon the intricate laws of thermodynamics, that the more practical engineers have avoided the subject as one which belonged only to specialists. The practical men have been left to themselves to make improvements, and have made slow progress because they did not possess the proper theoretical knowledge. In other words, that true combination of theory and practice which leads to the best results has been wanting among pneumatic engineers.

The whole question of compressed-air economy is based upon

* A lecture delivered before the Franklin Institute.

(1) Economy of production ;
(2) Economy of use.

Transmission calls for but little consideration. This statement will doubtless surprise many who look upon the losses suffered in the use of compressed air as due largely to transmission, and no better evidence is needed of the obscurity of the science, even among engineers, than this fact. There is not a properly designed compressed-air installation in operation to-day that loses over five per cent. by the transmission alone. The question is altogether one of the size of pipe, and if the pipe is large enough the friction loss is a small item. It is undoubtedly true that there are places where a conduit has been laid for a certain volume of air, and where the supply has been increased without increasing the size of the conduit, the result of this being that more air is forced through the pipe than its sectional diameter will admit economically ; hence the velocity of flow is increased, and as the friction is in direct proportion to the velocity, the loss of power is also increased. The largest compressed-air-power plant in America is that at the Chapin Mines, in Michigan, where the power is generated at Quinnesec Falls, and transmitted three miles. This is not an economical plant, but the loss of pressure as shown by the gage is only two pounds, and this is the loss which may be laid strictly to transmission. I recently visited the Jeddo Tunnel, near Hazelton, Pa., where compressed air at sixty pounds pressure is conveyed 10,860 feet. They told me that they had tried the gages on both ends of the line, and had found no difference whatever in pressure, but that the gages had been sent to the shops for repairs, as they were convinced that "something was wrong." The result was not changed when the gages had been "repaired," and it was evident that this apparently perfect economy of transmission was due to the fact, that a large pipe (five and three-fourths inches in diameter) was used to convey so small a volume of air, that the velocity in the pipes produced so small a friction loss that it could not be recorded on the gage.

A question commonly asked is, How much power is lost in using compressed air? I usually reply, fifty per cent., because a proper qualification of the question will result in figures in one case below and in the other above fifty per cent. If compressed air is produced by the best modern air-compressor, and used by the best modern engine *immediately at the compressor*, the loss is only that which is suffered when using any like engine, and is confined in its greatest extent to the question of engine friction, and is only to a small degree influenced by shrinkage of volume through radiation, clearance loss, leakage, etc. In such cases the loss varies between ten and twenty-five per cent., but such cases are rare, because it would obviously be more economical to use the steam direct.

The usual conditions of compressed air use are those where the air-engine is situated from 1000 feet to several miles from the compressor. In most cases the distance is so great that the compressed air enters the engine at a temperature equal to that at which it entered the compressor. Were it possible to produce compressed air isothermally, that is, without increase of temperature during compression, the service would be economical even at low temperatures, but isothermal compression has never been realized, and the heat produced during compression (which is the exact equivalent of the power applied) is suffered to increase the pressure, and hence to increase the resistance to compression, without a relative increase of volume. Hot air under pressure is discharged into a receiver, and the gage indicates a pressure of (say) sixty pounds, which is equal to that recorded by the gage 10,000 feet away, yet it is a false indication as affecting the question of power, because every cubic foot of sixty pounds air at the compressor is less in weight than an equal volume of equal pressure air at the engine, in exact proportion to the difference in temperature. The result of this is that an air-engine which uses (say) 100 cubic feet of sixty pounds air per minute at the temperature of the surrounding atmosphere, really uses about 150 cubic feet of sixty pounds air at the receiver temperature. All this is very important in looking for a remedy

for compressed-air losses, because it points to the influence of heat upon air, and the importance of reheating compressed air.

The loss of power in common practice where compressed air is used to drive machinery in mines and tunnels, is about seventy per cent. I refer to cases where common American air-compressors are used, and where the air is transmitted far enough to lose its heat of compression and is exhausted without reheating.

In the best practice, with the best air-compressors, and without reheating, the loss is about sixty per cent.

The losses may be reduced to a point as low as twenty per cent. by combining the best systems of reheating with the best air-compressors. In France, England and Germany, there have been erected during recent years large compressed-air installations. In Paris about 25,000 H.P. is transmitted over the city and is used to drive engines and for many other purposes. With a less efficient production than our American system, they have advanced beyond us in the use of compressed air. Reheating has been put into general use, while here in America the improvements have been more conspicuous in the air-compressor. Professor Kennedy, whose elaborate report on the Paris plant is accepted as an authority, uses the following words :

"Summarizing now the whole matter as regards efficiency, it may be said that the result of my detailed investigations is to show that the compressed-air transmission system in Paris is now being carried on, on a large commercial scale, in such a fashion that a small motor four miles away from the central station can indicate in round numbers ten H.P., for twenty H.P. at the station itself, allowing for the value of the coke used in heating the air."

Professor Kennedy concludes his report by saying, "Nothing, indeed, can be easier (as was evident on the recent visit of the Institution of Mechanical Engineers to St. Fargeau) than to point out various weak points in the arrangements adopted." We may reasonably expect to add to this fifty per cent. efficiency attained in Paris by an installation which combines the American compound condensing Corliss air-compressor with an efficient and economical reheating apparatus and Corliss or other economical engines.

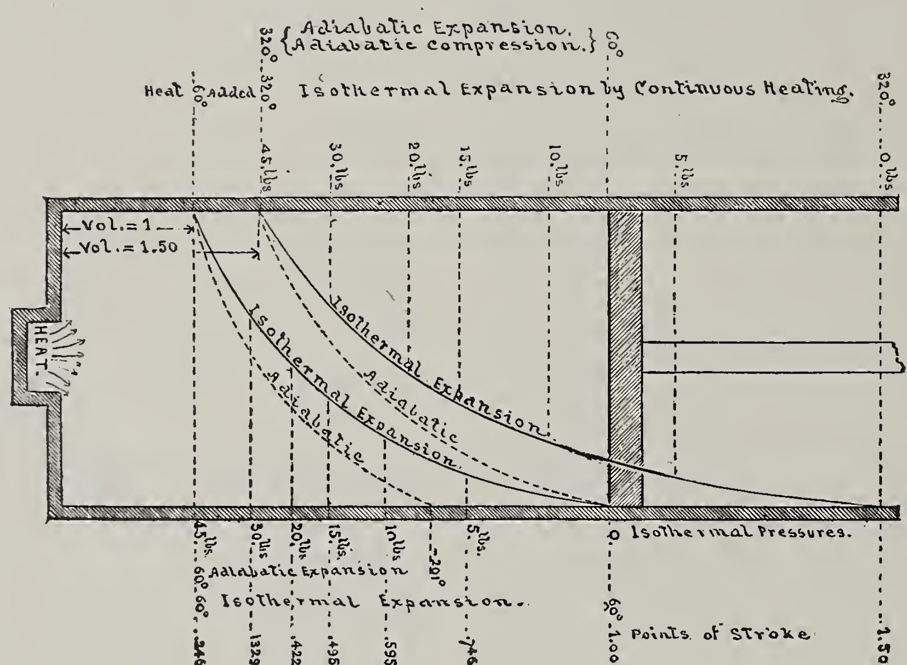


FIG. I.

The whole science of the production and use of compressed air can be best understood by a simple practical illustration.

Fig. 1 is an open cylinder which may be made to illustrate at the same time the air-compressor and the air-engine. The piston at the point shown is supposed to confine a volume of free air in the cylinder and at a temperature of

60°. Let it be pressed down until it reaches the point indicated by forty-five pounds at the left, and the pressure will follow the dotted lines marked "Adiabatic." This is, of course, assuming that the heat, which is invariably produced by compression, is suffered to remain in the air and to influence the pressure. We here have a confined volume of compressed air at a pressure of forty-five pounds and a temperature of 320°. Let there be no absorption of heat and the piston if released will return to the starting-point, the pressure following exactly the line indicated during compression and the temperature returning to 60°. In such a case we assume, of course, that the piston is frictionless. This points to the fact that compressed air is a perfect spring, and that the heat of compression when utilized can be made to return its full value of energy.

An air-compressor in spite of its cooling apparatus usually furnishes compressed air at pressures following closely the adiabatic line, so that the illustration applies to a typical case so far as the compression is concerned. This subject of adiabatic compression has been fully referred to, and the difficulties which have stood in the way of isothermal compression have been pointed out in a pamphlet written by me about a year ago, entitled "Compressed-Air Production," published by the *Engineering News* Publishing Company, New York.

We have now seen that the heat of compression is not such a serious thing, provided it can be utilized. The hot compressed air confined below the piston at the forty-five-pound point, if transferred through pipes or otherwise to an air-engine and maintained hot, will do as much work as we have just seen is possible when applied to the air-compressor itself in driving the piston back to the starting-point. To convey this air some distance hot, is a difficult matter, for compressed air, though very slow in taking up heat, has so low a specific heat that it parts with its temperature rapidly. This loss of heat is the only serious obstacle, because, as we have seen, the friction loss in the pipe is not serious, and experiments have conclusively proved that leakage in a good system cuts no figure in the loss of power. I have pointed out in "Compressed-Air Production" the reasons why clearance loss is of little consequence in an American air-compressor. This is especially true in adiabatic compression because here what little clearance there is serves only to confine hot compressed air, which acts as a spring, and which gives out a full return of power when the stroke is reversed.

As air parts with its heat rapidly, we cannot advise saving the heat during transmission by covering the pipe, so that we now suffer the loss of heat during transmission to go on, depending upon restoring the heat immediately at the air-engine. Now this reheating is not, as some may suppose, a means by which the gain is only equal to the expenditure. Air is almost a perfect gas, and the application of heat is a direct transfer of energy to a substance which, through its elasticity, is capable of giving a full return. We burn a pound of coal under the boiler, and get only about ten per cent. back in power, because of the large loss in the stack, the loss in the exhaust, the difficulties in the way of utilizing the latent heat, etc., but when we heat compressed air, the thermal energy in the coal is stored in the air, and we are only limited in our efforts to utilize all of it by the reduction of pressure which takes place more rapidly than the reduction of temperature, and hence a warm exhaust. Radiation of heat between reheater and engine is also a source of some loss.

Returning to Fig. 1, let us imagine that the piston has been stopped at the forty-five-pound point, and that this air, which, as we have seen, has a temperature of 320°, is transferred into a receiver and used at a point a mile away. The temperature will now be reduced to 60°, and if the system is well designed, we have nearly forty-five pounds pressure on the other end of the line, so that the volume of air will be reduced in size corresponding with the space underneath the lowest horizontal dotted line in the figure. This is marked "Volume 1." It is now used without reheating, to do work in an engine, and the line of reduction in pressure will now follow the lower dotted line marked "Adiabatic"

until it reaches the point marked,—201°,—which will represent the temperature of the air when exhausted at atmospheric pressure. We now see that instead of getting back to the starting-point the piston has only power enough to return about half-way.

If, on the other hand, heat were applied during expansion the pressure would follow the line marked "Isothermal Expansion" and the piston would return to the starting-point.

Another case is shown by the figure in which the air is compressed adiabatically to forty-five pounds, and heat enough is applied during expansion to maintain the temperature at 320°, until the air is exhausted at atmospheric pressure. This case illustrates the possibility of obtaining more power out of a given volume of air after compression than was expended at the compressor.

Reheating compressed air may be divided into two systems:

1. That in which the reheating takes place in the conduit and before the air passes the valve of the engine.

2. Reheating in the cylinder of the air-engine after admission and cut-off.

The first case is the common practice, and is of value in that it saves air volume. It cannot increase the pressure because there is a continuous elastic air connection between the receiver at the compressor and the heater. Compressed air which leaves the receiver at a temperature of 300°, and which passes through a large conduit, losing its temperature, maintains its pressure because of this continuous elastic connection.

The reheater serves to reduce the velocity with which the air is drawn through the pipe, because it delivers hot air to the engine at the same pressure as though there were no reheater, and the temperature being higher, the power in each cubic foot of air remains the same though the volume weight is less. This valuable service performed by the reheater is limited only by the fact that air-engines cannot work to advantage at temperatures over 350°; hence in a system that compresses air adiabatically to about sixty pounds pressure, and delivers it cold at a reheater, it is possible to restore the temperature to the original point, and thus lose in power only through friction of the compressor, consumption of coal in reheater, friction in conduit, leakage, etc.

The second case is a problematical one, as thus far it has not been found practicable to reheat directly in the engine. The only device which seems to offer encouragement in this line is the system of internal reheating, which the writer has applied with some success, and which will be described later on. By internal reheating directly against the piston of the air-engine an enormous advantage can be gained, and, as shown by Fig. 1, more power may be derived from a volume of compressed air than was originally expended at the compressor. This additional power has been derived directly through heat acting upon the intrinsic energy which was stored in the free air before it entered the compressor.

The Paris reheater is simply a coke stove which surrounds the air-pipe. It has been modified in various ways and at several places. The flue surrounds the air-pipe nearly up to the steam-chest of the engine, so that very little heat is lost. Radiation is also reduced to a small figure. Professor Kennedy tells us: "The air was heated in passing through the stove up to 315° F. with a consumption of about 0.39 pounds of coke per I.H.P. per hour. As the admission temperature of the cold air was 83° only, this corresponds to an increase of about forty-two per cent. in the volume of the air and should therefore (had the indicated efficiency remained the same) have been accompanied by a decrease of air consumption in the ratio of one divided by 1.42 or 0.70 inches. The air used in Paris is about eleven cubic feet of free air per minute per indicated horse-power. The ordinary practice in America with cold air is from fifteen to twenty-five cubic feet per minute per indicated horse-power. In Professor Kennedy's experiments the engines were found to consume about fifteen cubic feet of air per minute per indicated horse-power without reheating.

The amount of fuel consumed during reheating is trifling. With the reheaters commonly employed it amounts to from one to two cents per horse-power per

day. A more economical system of reheating will reduce these figures considerably. Professor Kennedy says of the Paris reheaters, "It would not be difficult to design a more economical stove."

Fig. 2 illustrates a reheater in which the air is brought in contact with the fuel. The illustration is taken from a case which was put into actual service in connection with a rock-drill. Immediately above the throttle-valve and near the steam-chest was placed an enlarged pipe-fitting, in the interior of which, a little above the center, was fixed a piece of wire gauze; above this gauze charcoal was thrown, some of it being in an incandescent state. The whole chamber was closed and the compressed air turned on. The air was thus brought in direct contact with the burning charcoal and was admitted to the drill cylinder extremely hot. With the consumption of a piece of charcoal an inch and a half in section and about two inches long, about two feet of hole were drilled. Instead of charcoal a substance called sestalit has been used with success, the advantage of sestalit being that it remains ignited for some length of time after the air has been shut off, and the products of combustion when discharged in a confined space are not objectionable.

The system of reheating by internal contact is theoretically the most perfect, because the full value of the heat units in the fuel are transferred to the air. The air-pipe is at the same time the combustion chamber and the flue, the products of combustion adding about five per cent. to the volume of the air, in addition to the large increase through expansion by heat. Box is authority for the statement that "When oxygen and carbon combine, the volume of the carbonic acid gas formed is nearly the same as that of the oxygen consumed; when, therefore, a combustible contains carbon only, the volume of gas in the chimney is the same as that of the air entering the fire, expanded of course to the volume due to the increased temperature, the oxygen consumed having been replaced by the same volume of carbonic acid gas. The nitrogen in the air is passive, passing through fire without chemical alteration. If the combustible contains water already formed and with which it is more or less saturated, vapor is formed from it and is added to the products of combustion."

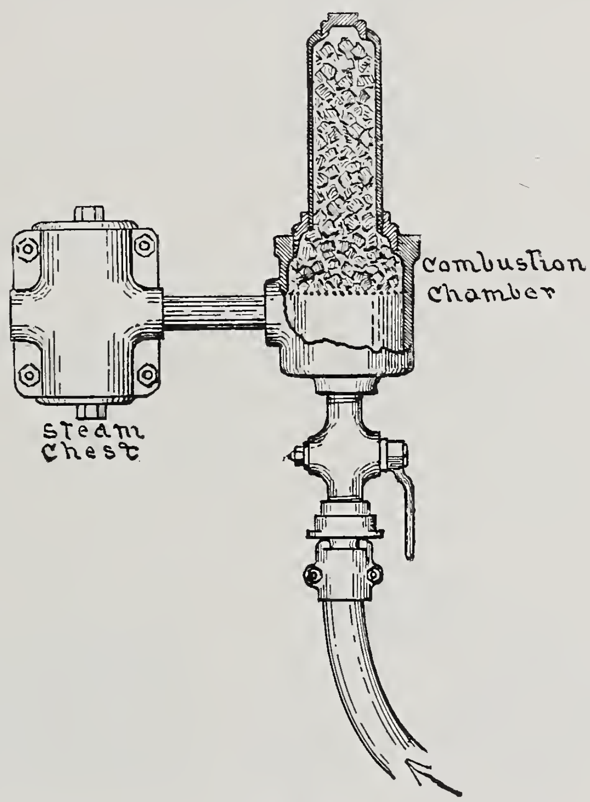


FIG. 2.

A simple reheater is shown in Fig. 3. A common lamp is placed within the air-pipe, the oil being supplied to the lamp by means of a hand-pump. I

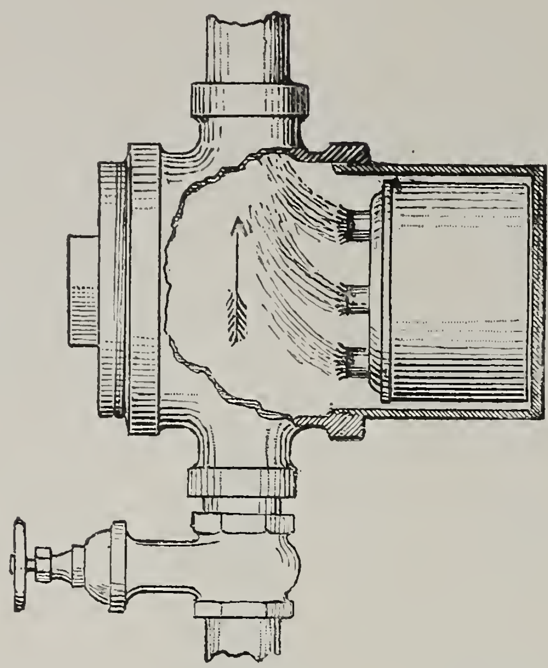


FIG. 3.

first applied this system to one of the pipe-lines on the new Croton aqueduct, using a common miner's lamp placed in a four-inch pipe.

Fig. 4 illustrates an electric reheater.

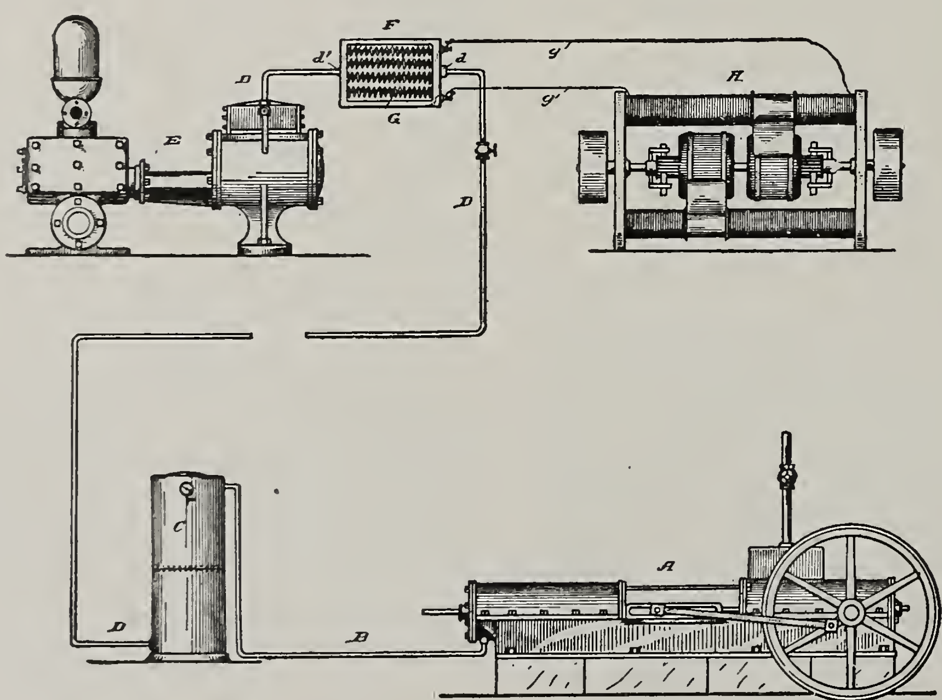


FIG. 4.

The air-compressor is shown at A, compressed air being conveyed through pipe B to receiver C, thence through a conduit D to a pump E, situated (say) a mile away. In the engine-room with the compressor is a dynamo H, which serves to light the mine. At a point near the pump a resistance-coil F is placed in a chamber communicating directly with the compressed air. This resistance-coil is made of any highly refractory substance, which resists the passage of a current to such an extent that the electricity is converted into heat, and the heat is thus imparted to the compressed air. Such a reheater as this has many advantages. The entire

absence of combustion makes it perfectly safe for inflammable mines, and the ease with which it is applied by simply opening or closing a switch recommends it. It is also a cheap device and has been applied recently in the shape of a simple coil of wire placed in an air-pipe. The conversion of electricity into heat is an economical one, it being a well-known fact that a current of any potential, when intercepted by sufficient resistance, may be entirely absorbed and returned as heat. This is accomplished unit for unit, and as the loss in electric energy through transmission is low when compared with the shrinkage which takes place in compressed air, we here have a means by which the efficiency of the whole system may be increased by calling upon the electric wire to reheat the compressed air.

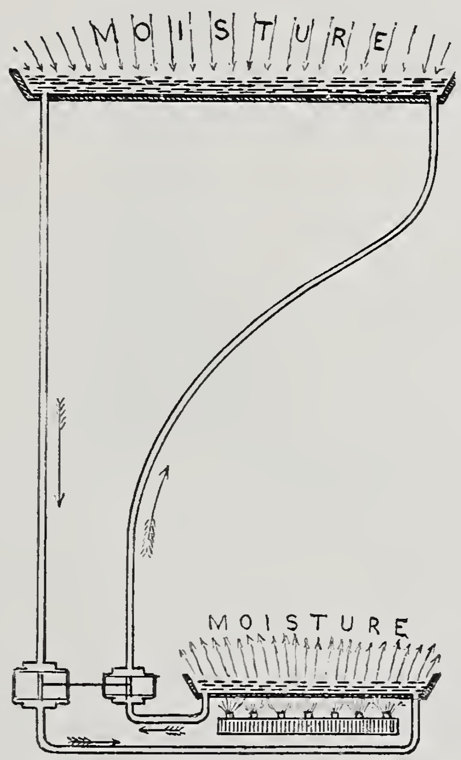


FIG. 5.

That it is theoretically possible to obtain from hot compressed air more power than was expended at the compressor, has been shown in Fig. 1. That this may not be confounded with perpetual motion but may be made clear, I have prepared a sketch, shown in Fig. 5.

Sulphuric acid in its concentrated form will, when exposed in an open dish, absorb moisture from the atmosphere to the extent of about double its weight. A hypothetical assumption is made of a pump arranged to discharge sulphuric acid in the direction shown by the arrow to an open dish elevated (say) 100 feet. The amount of power necessary to discharge a certain quantity of sulphuric acid into this dish, is exactly equal to the power which the sulphuric acid is capable of giving out when falling back again, less the friction of the pump, leakage, etc. Now let us assume that the sulphuric acid in the open dish remained there long enough to absorb moisture from the atmosphere until its weight has been doubled; it will thus obviously have twice the amount of power in falling back again, and if the friction and leakage losses were not too great it will be capable of driving the pump, and of returning an equivalent volume of the concentrated acid to the dish. If the same acid is used over again the moisture must be driven out, and lamps are shown in the sketch provided for this purpose. The analogy between this hypothetical case of sulphuric acid and one of compressed air is, that, as with acid we may draw power from moisture which is contained in the air, so with compressed air may we draw upon the intrinsic heat energy of the atmosphere.

These thoughts suggest the advisability of defining still further what is meant by intrinsic energy. Air being a practically perfect gas it will expand or contract in volume through a definite range in proportion to its temperature. Experiments made with air at temperature between the freezing and the boiling points of water, have given us the ratio of contraction of volume by reduction of temperature from which the absolute zero has been determined. The absolute zero of air is about 461° Fahr., and is that point at which any volume of air of air at 100 pounds gage pressure and 60° temperature. One pound, or thirteen cubic feet, of air at fifteen pounds pressure and 60° temperature, is represented by the space *C*. The available power in this air is 21,469 foot-pounds. By available power is meant the amount of power which can be utilized when this air is expanded adiabatically to atmospheric pressure. The diagram shows that when such pressure is reached the temperature will be 57° Fahr. There still remains in this air a certain amount of intrinsic energy and

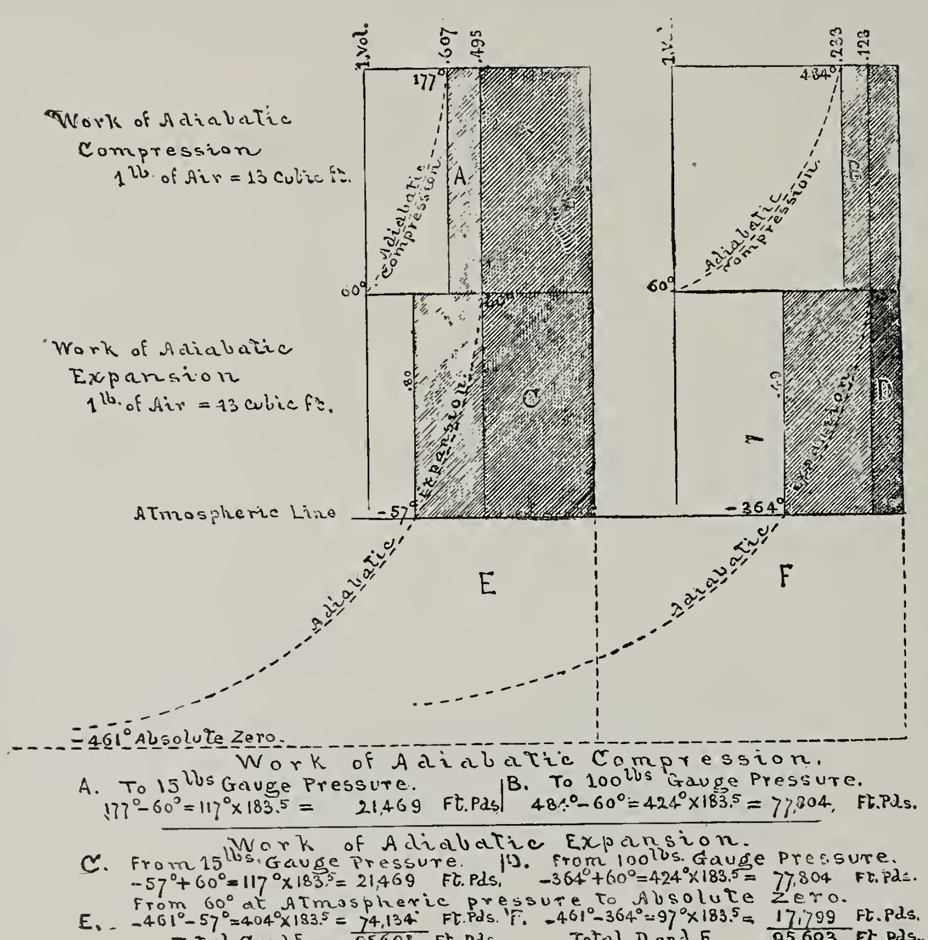


FIG. 6.

is reduced to nothing through expansion. In other words, the air may be said to be condensed at 461°. We have therefore a base line which limits the power contained in any body of air.

Fig. 6 is a graphic diagram drawn for the purpose of illustrating the fact that the power which is contained in any body of air at a given pressure is dependent upon its distance in temperature above the absolute zero, and that there is as much power in a pound of air at fifteen pounds gage pressure and 60° temperature as there is in one pound the diagram and figures show that this energy is equal to 74,134 foot-pounds. This added to the available energy gives us 95,603 foot-pounds as the whole energy contained in one pound of air at fifteen pounds pressure and 60° temperature.

D represents one pound of air at 100 pounds pressure and 60° temperature. Its available energy is 77,804 foot-pounds, and its intrinsic energy is 17,799 foot-pounds, or the total energy is 95,603 foot-pounds, which is exactly equal to the case just cited.

These figures prove the correctness of that thermodynamic law, which states that the power of any elastic gas is in direct proportion to its height of fall. So long as the temperature is above the absolute zero, there is as much power in the same body of air when expanded adiabatically from a moderate temperature to an extremely low one, as when expanded from a high temperature to a moderate one, and this offers to some extent a limitation to that system of reheating which increases the volume without at the same time increasing the pressure.

Fig. 7 is a diagram which illustrates a typical case in American practice, where air is admitted to a compressor at 60° and compressed adiabatically to 100 pounds pressure. It is then transmitted a sufficient distance to cool it down to 60° temperature and expanded back to atmospheric pressure, the temperature falling to 364°. The conditions shown in the diagram are extreme and purely theoretical. In actual practice both compression and expansion are only approximately adiabatic.

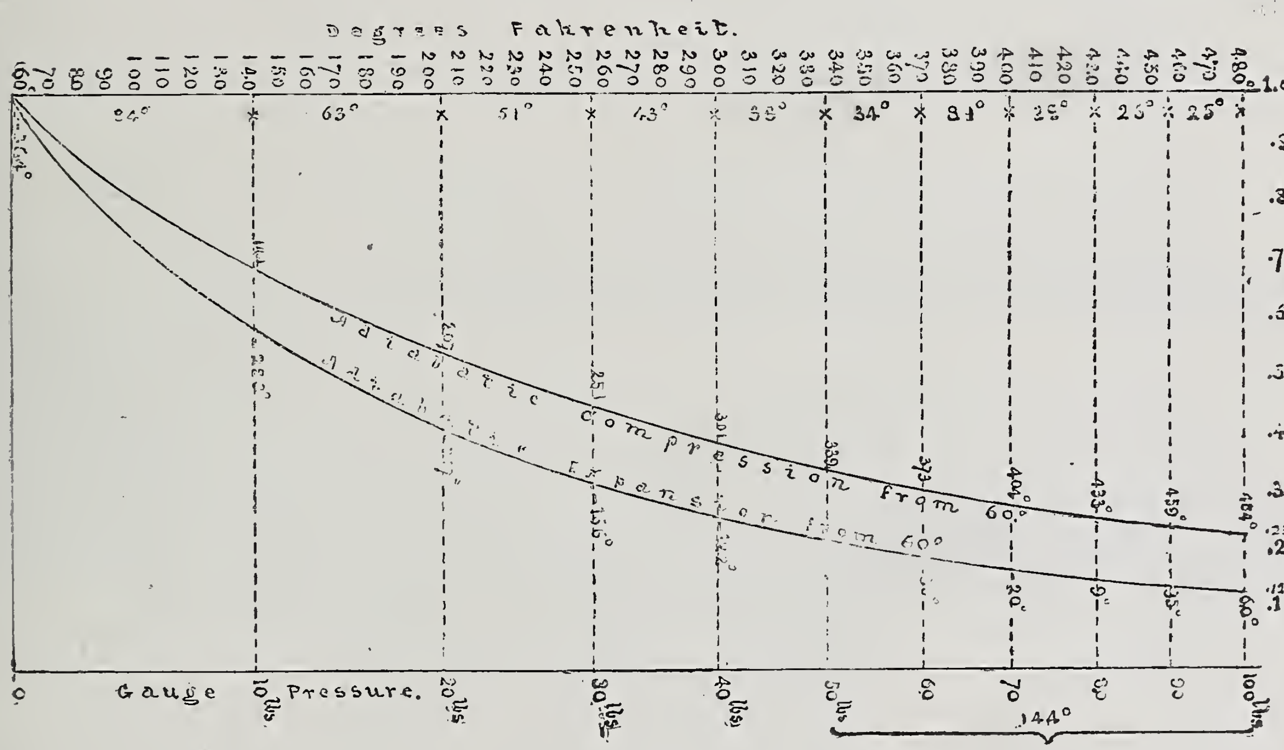


FIG. 7.

Fig. 8 illustrates an economical condition of compressed air use in mines and tunnels. The power is generated electrically and is conveyed by wire to a point within a few hundred feet of the heading where a rock-drill is at work. By means of an electric air-compressor hot compressed air is produced adiabatically, and is expanded adiabatically in the cylinder of the drill, following closely the economical conditions illustrated and described in Fig. 1. Such a state of things as this admits of an electric installation in the mine for the purpose of haulage, lighting, traction, and pumping, to all of which uses electric energy has been successfully applied, and it gives us a means by which a compressed-air drill may be successfully and economically operated at the heading. The air may be taken from the mine and when exhausted at the drill it serves to keep up a circulation in so confined a space as a heading, and as it is exhausted at atmospheric temperature there is no material change in the temperature of the mine. In some cases the air may be drawn through a flue from the outside, and thus through compression and expansion it will serve to ventilate the mine, as it does in the case of a compressed-air installation. The economy of the system depends to its greatest extent upon the economy of electric production and transmission. Electrical engineers tell us that they can deliver electric energy several miles from the generating station with an

efficiency of eighty per cent. If this is true its conversion into compressed air and its use as a power under the conditions shown in the illustration may be accomplished at a very moderate reduction of efficiency, because, as is plainly seen, the losses commonly incurred in compressed-air service do not here take place. Electric rock-drills are subject to many costly limitations. Thus far they have not been successful, and it is a serious question whether or not it is possible to accomplish the drilling of rock by the percussive principle (which is the only true one), by an electric engine which will be equal in weight, in price, and efficiency to an air-engine. The weight of a rock-drill is one of its most conspicuous limitations, and from every basis of theory and practice a

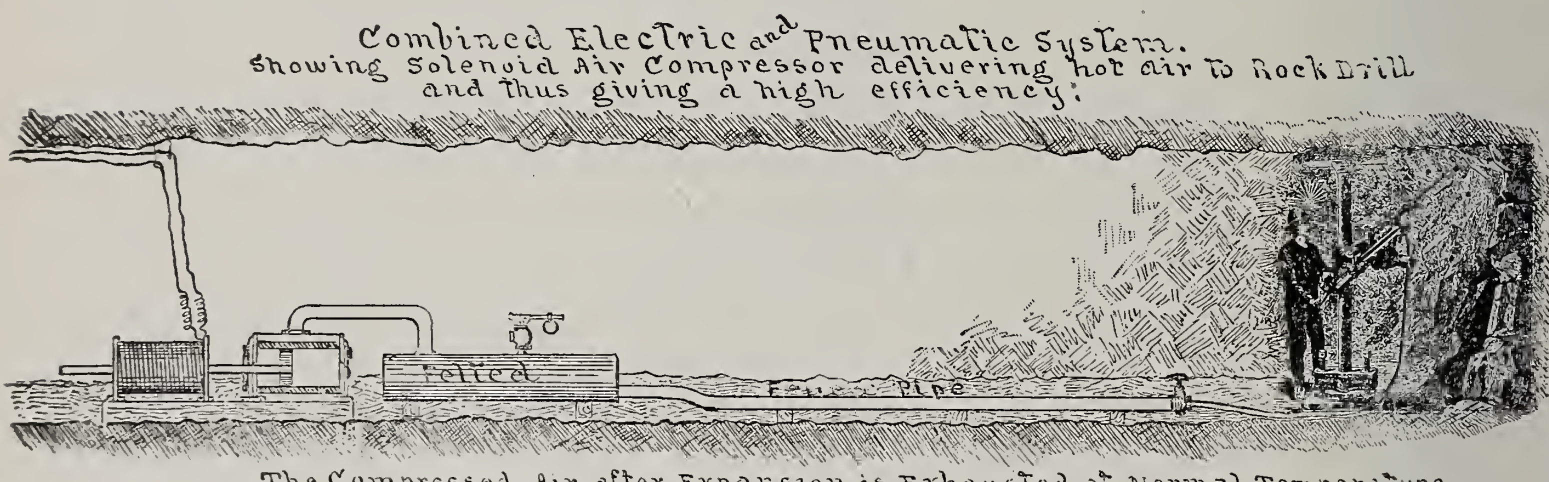


FIG. 8.

compressed-air percussive engine will weigh less than half that of an electric one of the same power. An electric drill is made of copper, which cannot compete in price with iron, and the durability of the apparatus is apparently in favor of the air-drill. But as mines are likely to be lighted by electricity, and as there are many conditions of work favoring electric transmission for other purposes, we here have a means by which all the advantages of the air-drill are maintained in an electric installation.

Fig. 9 illustrates what may be called an endless chain of pneumatic power. An air-compressor draws its supply of air from a receiver in which there is a pressure of twenty pounds. The air is compressed to sixty pounds, and is carried down a shaft and used to drive a pump. The exhaust of the pump is returned to the initial air-receiver, and thus the same air is used over and over again, all of the exhaust pressure being utilized. As pumps usually exhaust at pressures from twenty to fifty pounds, a large saving is effected in this alone.

When starting, it is simply necessary to open a valve on the initial air-receiver until a pressure of sixty pounds has been reached in the secondary receiver; the valve is now closed and the work goes on. The economy of this system is apparent. The heat of compression is converted into work in the pump, and a very low temperature of air is maintained. The econmy of low initial temperature in air compression has been fully set forth in a diagram which I have published in "Compressed-Air Production" and a power diagram of such a system as this indicates several other economical points, notably the admission of compressed air instead of free air through the inlet valves, which serves to reduce the heat loss during compression and to equalize the resistance strains in the engine.

Fig. 10 illustrates in contracted form a complete pneumatic installation comprising boiler, air-compressor, air-receiver, air-injector, supplementary air-receiver, pipe for transmission, reheater, and air-engine. The reheater and air-engine should be considered as situated from 1000 feet to several miles from the compressor.

It will be observed that atmospheric air is drawn in the piston inlet tube

of the compressor at 60° temperature. It is compressed adiabatically; that is, without any provision for cooling during compression, and in this way all of the power expended in the steam cylinder is converted into heat, which remains as power in the air. Perfect adiabatic compression, as previously stated, cannot be attained because of the absorption of heat by the metallic surfaces, radiation, etc. For the sake of illustration, however, the figures are given at adiabatic compression.

Now, we have seen that, if all of this heat can be utilized, it will return 100 per cent. in power, less such small items as friction, leakage, etc., and the purpose of this sketch is to call attention to a means by which at least a large part of this heat may be saved, and not wasted by radiation into the atmosphere or by absorption in water. An air-injector is located between two air-receivers, and the highly compressed or the highly heated air from the first receiver is admitted through the nozzle of this injector, and is thus converted into high velocity inducing free air from the atmosphere, and discharging an increased volume at a reduced pressure and temperature into a secondary receiver. For the sake of illustration, the pressure in the first receiver is taken at 100 pounds and is reduced to fifty pounds.

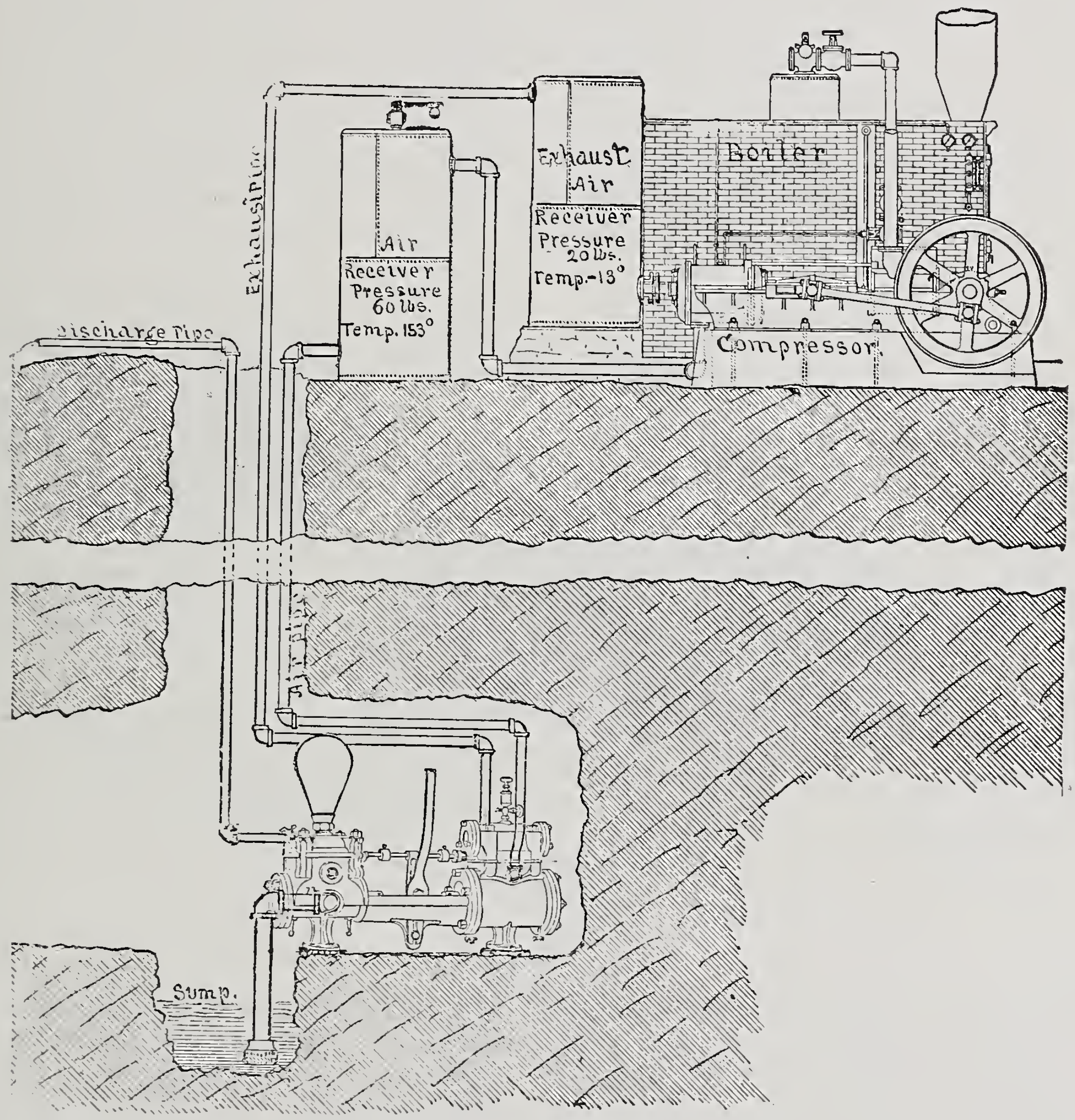


FIG. 9.

This air-injector has been tried with success, though the experiments have not gone far enough to determine to what extent it will effect a saving in the production of pneumatic power. It has been found that with a pressure of eighty pounds in the first receiver, the injector will work discharging and inducing free air into a second receiver in which is maintained a pressure of sixty pounds.

This difference of pressure may obviously be modified by the shape of the nozzle, sizes of pipes, etc., and it is probable that the injector may be made to work at a difference between the two pressures of only ten pounds.

The principle is similar in many respects to that of the boiler-feed injector about which there are so many mysteries. We know that not only is it possible to feed a boiler through an injector which takes the steam at a pressure lower than the boiler pressure, but the exhaust injector is a practical success. That we may exhaust steam from an engine and, by means of such exhaust, feed water to the boiler which supplies the engine with live steam, is indeed a mystery, and it is fair to assume that equally valuable and surprising results may be obtained from the induced air-injector.

Mr. Green, the inventor of the Green system of ventilation, which is used on Transatlantic steamers, is now conducting experiments looking toward the ventilation of the Forty-second street tunnel, New York, by means of air induced through an injector. His experiments have shown that one volume of air when passed through the nozzle of an injector at a pressure of five pounds will induce thirty volumes of free air; that is, a volume efficiency of thirty to one. Mr. Green measured his air by means of a meter.

His conditions were similar to that outlined in the sketch, differing only in degree, and while it is not expected that so large a percentage of volume in free air may be induced, yet on the basis of figures alone, when compared with Mr. Green's experiments, we might expect from three to five volumes.

The velocity with which compressed air is discharged through a nozzle does not differ materially at pressure of fifteen pounds and over. The actual velocity with which compressed air at five atmospheres is discharged through a short pipe is 658 feet per second, and at ten atmospheres the velocity is 649 feet per second. This is because high-pressure air is more dense than air at low pressure, and just in proportion as the density increases does its resistance to movement increase. This is one of the limitations to the pneumatic dynamite gun. They started on about 500 pounds pressure and fell short of the mark. It appeared that it was only necessary to increase the pressure to increase the range, but the limitations were soon discovered.

With air discharged through an injector nozzle at a velocity of 650 feet per second, it is easy to understand that free air will be induced and discharged with it into a secondary receiver. The nozzle should be constructed so as to offer the maximum amount of contact for the minimum volume of discharge, and such a nozzle has been built by Mr. Green;

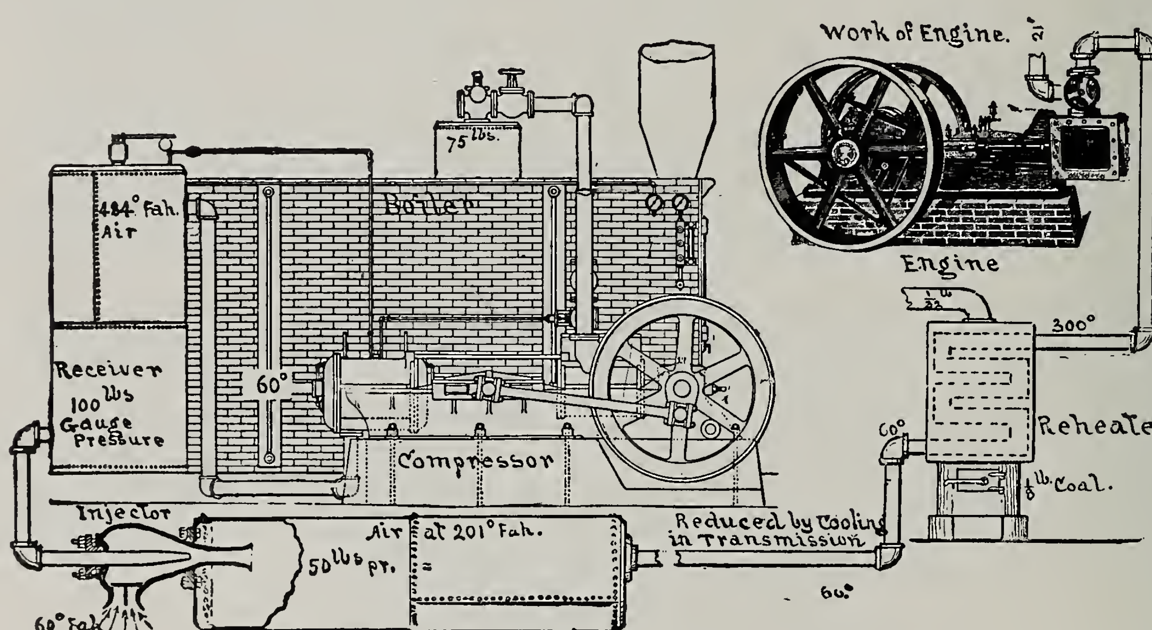


FIG. 10.

it takes hold of the induced air not only on the outside but also directly in the center or cord of the jet.

This is not a case where something is sought from nothing. The hot compressed air is converted into high velocity and thus the heat of compression is utilized. Were it not utilized in this way it would simply be discharged into the atmosphere by radiation, which is the usual practice in long-distance transmission in America.

Compressed air cannot be produced isothermally. In spite of the best system of injection combined with water-jackets and a complicated apparatus, there will still be the heat of compression influencing pressure during compression. Compressors have been made which show cold discharge-pipes and passages, and cold air in the receiver, but the largest part of this reduction in temperature has taken place after compression. If we cannot keep down the heat during compression, and if it be true that in keeping it down even to a reasonable extent large complications are involved in the machinery, why not let it be produced and so simplify the apparatus, then let this hot high-pressure expanded air be discharged through one or two injectors until its temperature has been reduced to a point approximately what it will inevitably reach during transmission, and thus we have converted the heat of compression into air volume. The reheater shown in sketch is little more than a common stove, the air-pipes passing through the furnace. This saves volume of air only, it cannot increase the pressure. The engine which is driven by the compressed air should be provided with an automatic cut-off, and to insure economy it should exhaust at atmospheric pressure. It is obvious that when exhausting at atmospheric pressure it will also exhaust at a comparatively high temperature, unless the air is first admitted at a pressure sufficiently high to admit of early cut-off and complete and economical expansion. This points to economy under some conditions by using high-pressure air in an engine which works in connection with a system of reheating, and it also points to the highest economy which will be shown by that system which follows the conditions shown in the sketch, but which reheats or rather explodes the compressed air behind the piston of the air-engine after admission and cut-off. This principle has been verified to some extent in certain oil- and air-engines, notably the Priestmann and Grigg, which have recently been brought to the attention of engineers.

THE MEASUREMENT OF POWER.*

By Thomas Gray.

ONE of the most important, and at the same time most troublesome, problems in mechanical engineering is the measurement of the power produced by a motor or given to a machine. In this paper a brief description is given of the principles of three forms of dynamometer which have been used for this purpose with fairly successful results.

I. Fig. 138 illustrates a form of dynamometer which may be used either to measure the power given to any machine, as, for instance, a dynamo, or to measure the total power given out by an engine which is driving a number of machines. Suppose that *B* is the crank shaft of an engine. A cross-head such as for a different purpose, is here represented by *J*, is keyed to the shaft, and the pulley *P*, which in this case is the driving pulley, is connected to the shaft by means of four links, *E*, *M*, *F*, *N*, connecting the cross-head to a pair of double bell-crank levers, *KLO* and *CDG*, mounted on bearings fixed to the pulley. The ends of the arms *O* and *G* bear against one end of a rod *R* passing along the axis of the hollow shaft of the pulley. When the shaft *B* is turned, two of the arms of the cranks, as *F* and *M* or *E* and *N*, are pulled toward the cross-head, and thus tend to push the rod *R* outward. This is resisted by the bell-crank lever *S*, which is supported by a plate resting on a diaphragm which closes the top of the cylinder *T*. The cylinder *T* is either partly filled with mercury and partly with water, or filled with water and piped to a mercury or other form of pressure gage placed in any convenient position. The pressure on the end of *R* is thus resisted by a column of mercury, the height of which will be directly as the pressure and inversely as the size of the plate resting on the diaphragm. Thus by finding the indication of the gage when a known pull or push is applied to *S* at the point of contact *R*, the turning moment exerted by the engine can be calculated for that value of the reading on the gage. The effect of centrifugal force on the levers attached to the pulley *P* must be designated, and this is done by counterpond masses applied as indicated by the dotted lines inside the pulley. When the speed of the engine is known, the indications of the pressure-gage give the means of determining the horse-power being transmitted at any instant. When a record of the variation of the resistance which the engine experiences is required, the tube *V* is provided with a float carrying a recording pen, and a record drum is mounted and driven either by clockwork or by the engine itself. In cases like those of electric street-car service very interesting and instructive records are thus obtained, showing the maximum power required, and the fluctuations of power which occur in such service. The area of the record between the zero line and the line drawn by the recording pen is proportional to the whole work done in the time during which the record is made. This area can be very accurately and quickly obtained by cutting it out and comparing its weight with that of the same length of the whole breadth of the paper ribbon. A better method of mounting the dynamometer as an energy meter is to mount a light counter on the float and allow one wheel of the counter to be driven by contact with the face of a disk which is driven by the engine. The friction-wheel of the counter should be on the center of the disk when no work is being transmitted.

In the designs of the dynamometers built for use in the shops of the Rose Polytechnic Institute both the recording pen and the integrating apparatus have been included, but the integrator has not yet been attached to any of them. Arrangement can very easily be made

* Paper read before the American Society of Mechanical Engineers.

in this particular form for checking the zero, as the thrust of R can be easily taken up by a collar, leaving S free and thus bringing the pen and friction-wheel to zero.

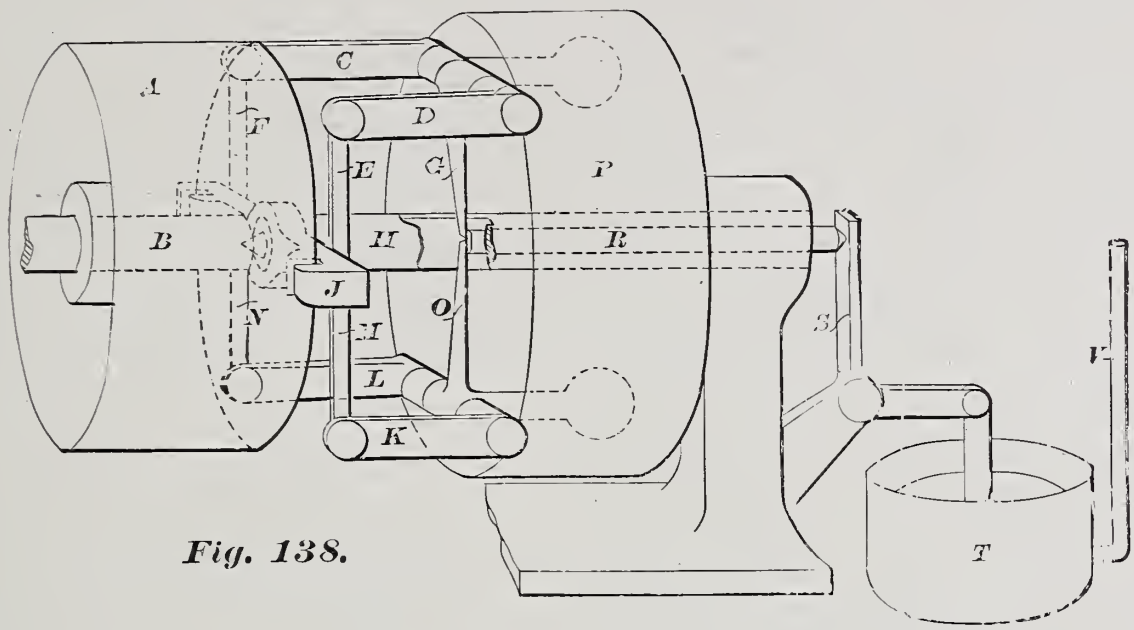


Fig. 138.

When the dynamometer is used to measure the work given to any particular machine, P becomes the pulley driven by the belt, and A the pulley of the machine. The cross-bar J is clamped to the pulley, and the action is the same as that just described.

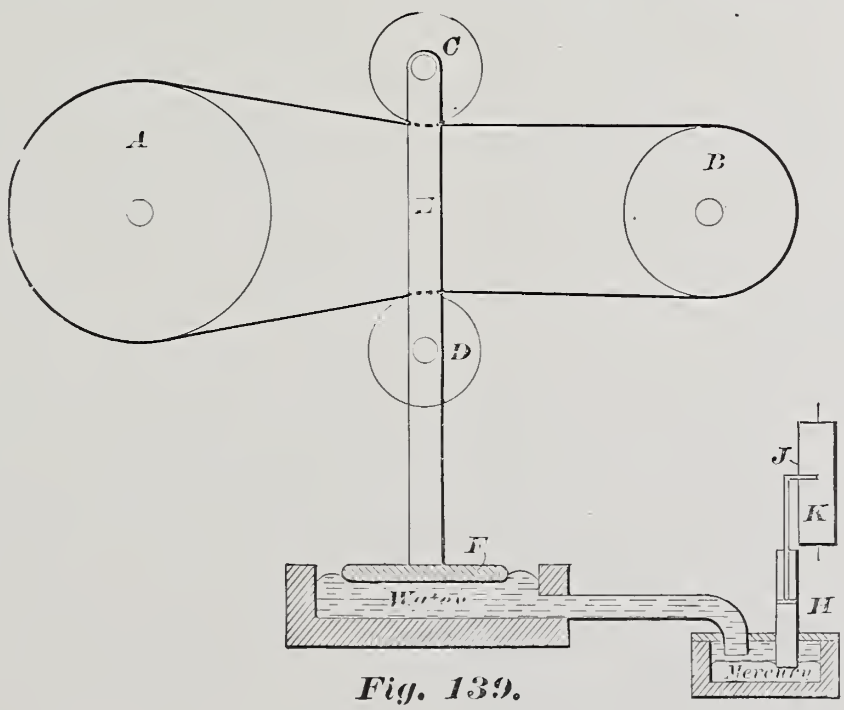


Fig. 139.

II. Another form of dynamometer, which has been used with good results, is illustrated diagrammatically in Fig. 139. In this case let A be the driving and B the driven pulley. Two pulleys, C and D, are mounted on a frame E, and properly supported, so that they can be pulled together on the belt. The frame E is supported by means of a plate F resting on a diaphragm as shown. The whole weight of the frame together with the weight of the deflected belt should, however, be independently supported, so that a change of length of the belt while running does not affect the indications. The water under the diaphragm transmits any change of pressure on the plate F to the pressure gage, which, as in the case above described, may be of any ordinary form if a record is not required. When a record is required a similar method to that de-

scribed in connection with Fig. 138 may be adopted, and a mercury column gage is actually used on the instrument under consideration. The lower belt being supposed the driver, it becomes tighter, and the upper slacker as the power increases; thus greater pressure is thrown on the plate *F*. This, however, does not sensibly change the positions of the pulleys or the deflections of the belt, which must be stretched sufficiently to prevent the upper half of the belt becoming slack when the maximum power is being transmitted. This apparatus may be standardized statically by placing a weight on the belt above the pulley *D*, but when possible it is better to standardize it by causing the machine to do a known or measured amount of work. In many cases this can be readily done by means of a brake. In the case of electrical machinery a definite increase of work may be obtained and measured electrically.

A part of a diagram of work taken from a test of the Terre Haute Electrical Street Railway is given in Fig. 140. This diagram is interesting as showing the extremely rapid variation of the power which the engine was called upon to deliver, and the promptitude with which the call was responded to by the belt. Variation of speed is not taken account of here, as no separate time-marker was placed on the apparatus. The time scale marked on the diagram is therefore to be taken as simply the average speed of the paper. The diagram here shown is similar to the remaining portion, which contains the record of a complete day's work, and is therefore of considerable length.

III. Perhaps the most interesting of the dynamometers here described is that the principle of the arrangement of which is illustrated in Fig. 141. In this figure *B* represents the belt which is supposed to be driving the pulley *A*. Bearing on the belt and just clear of the pulley two measuring-wheels *C* and *D* are fixed. These measuring-wheels communicate their motion to two counting wheels *H* and *J*, one of which, *H*, carries a dial, while the other carries a pointer *K*. Both the dial and the pointer are turned in the same direction, so that, if both pulleys *C* and *D* make the same number of turns, the pointer *K* and the dial *H* turn at the same rate. When the belt is called on to transmit work, however, the tight side of the belt runs faster than the

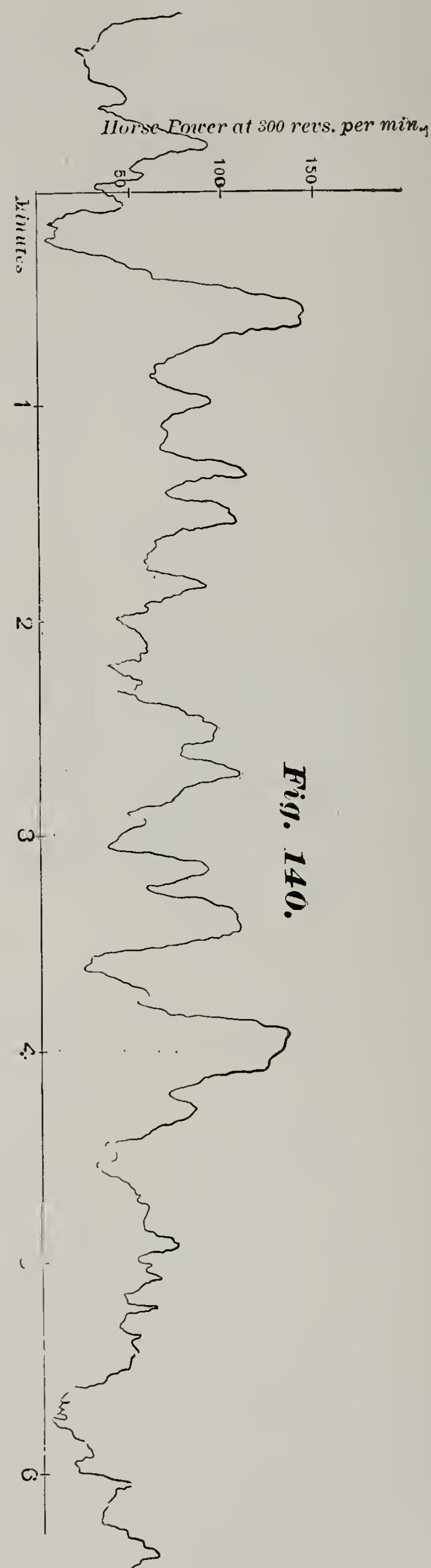


Fig. 140.

slack side on account of its smaller section. What is commonly known as the elastic creep of the belt is increased, and hence one of the pulleys makes a greater number of turns per minute

than the other. Either the dial or the pointer goes ahead, and the rate of gain is proportional to the rate of working, while the total gain in any time is proportional to the total work done in that time. This dynamometer, as it has been made for laboratory use, has provision for adapting the distance between the pulleys *C* and *D* so as to fit any size of pulley *A* up to six feet diameter. The whole is mounted on a shaft, which, when the machine is in use, forms a continuation of the driven shaft, while *F C* and *G D* are carried by arms which allow the counting wheels to be placed at different angles apart on the driven pulley. The object of this is to enable the gradual increase of speed of the belt as it passes from the slack to the tight side to be illustrated. In this particular dynamometer there is a double worm and gear reduction between *C* and *J*, and between *G* and *H*, which causes 2500 turns of the counting wheels to give one turn of the dial and pointer. One per cent. of creep thus causes the relative motion of the dial and index to be one turn for 250,000 turns of the wheels *C* and *D*. With wheels one foot in circumference, and a belt speed of 5000 feet per minute, which is nearly the actual case for one of our dynamos, we get one turn of the index on the dial in 50 minutes. Full power gives considerably more than this, and therefore for continuous working the speed of indication is fast enough. For a power indicator with slow-speed belts the reduction is too great, as in this case it should be possible to measure the work done in one minute accurately. For such purposes it is intended to put on a steady deflection indicator worked by the counting wheels. Suppose, for example, an axis driven by *C F* and carrying a wheel turning with the shaft, but free to move sideways. Let this wheel run in contact with the face of a disk driven by *D G*. The wheel will move to the position on the disk where there is no slip, and it can therefore be made to turn a pointer and indicate the rate of working at any instance.

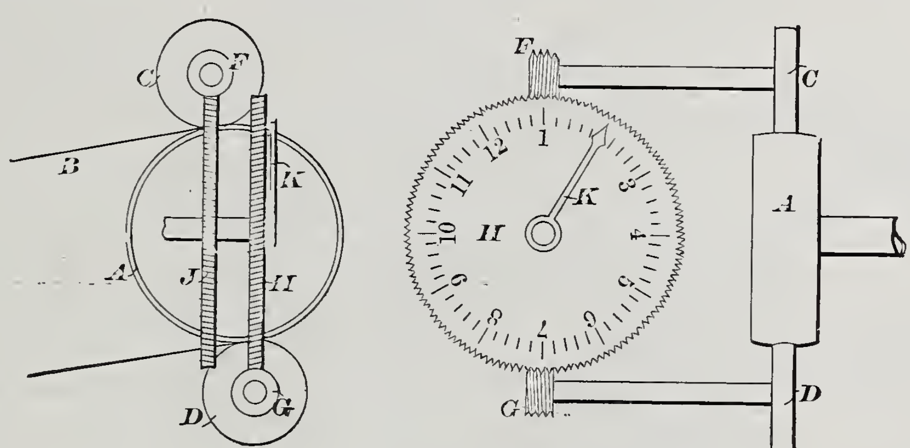
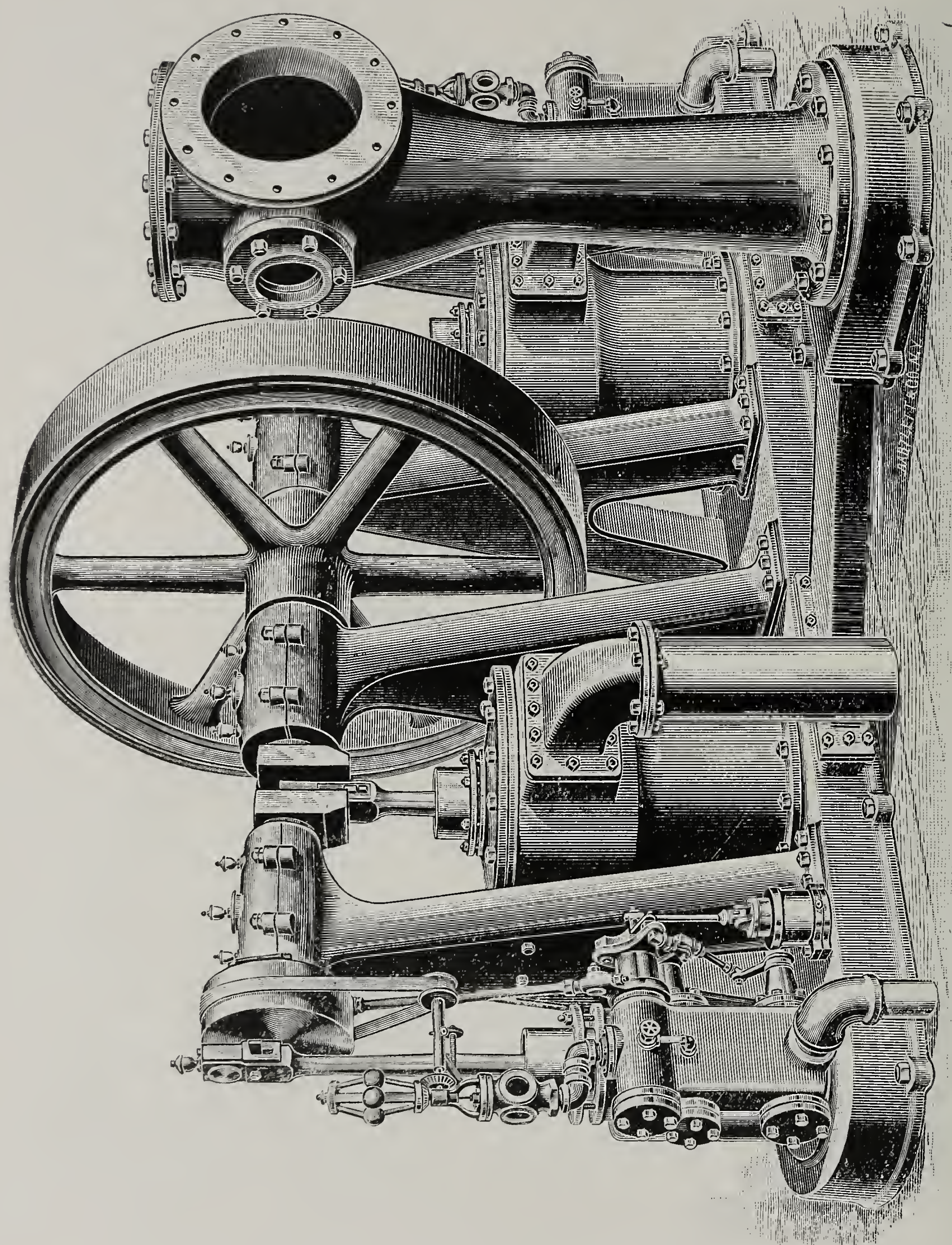


Fig. 141.

No attempt has been made to give details of construction. The object has been simply to point out the principles on which these dynamometers act ; anyone wishing to use similar devices will readily supply the details of construction suitable for his particular case. I have to express my obligation to my colleague, Prof. Ames, without whose assistance in preparing the diagrams I could not have presented these papers.



A NEW INDEPENDENT CONDENSER.

A NEW INDEPENDENT CONDENSER.

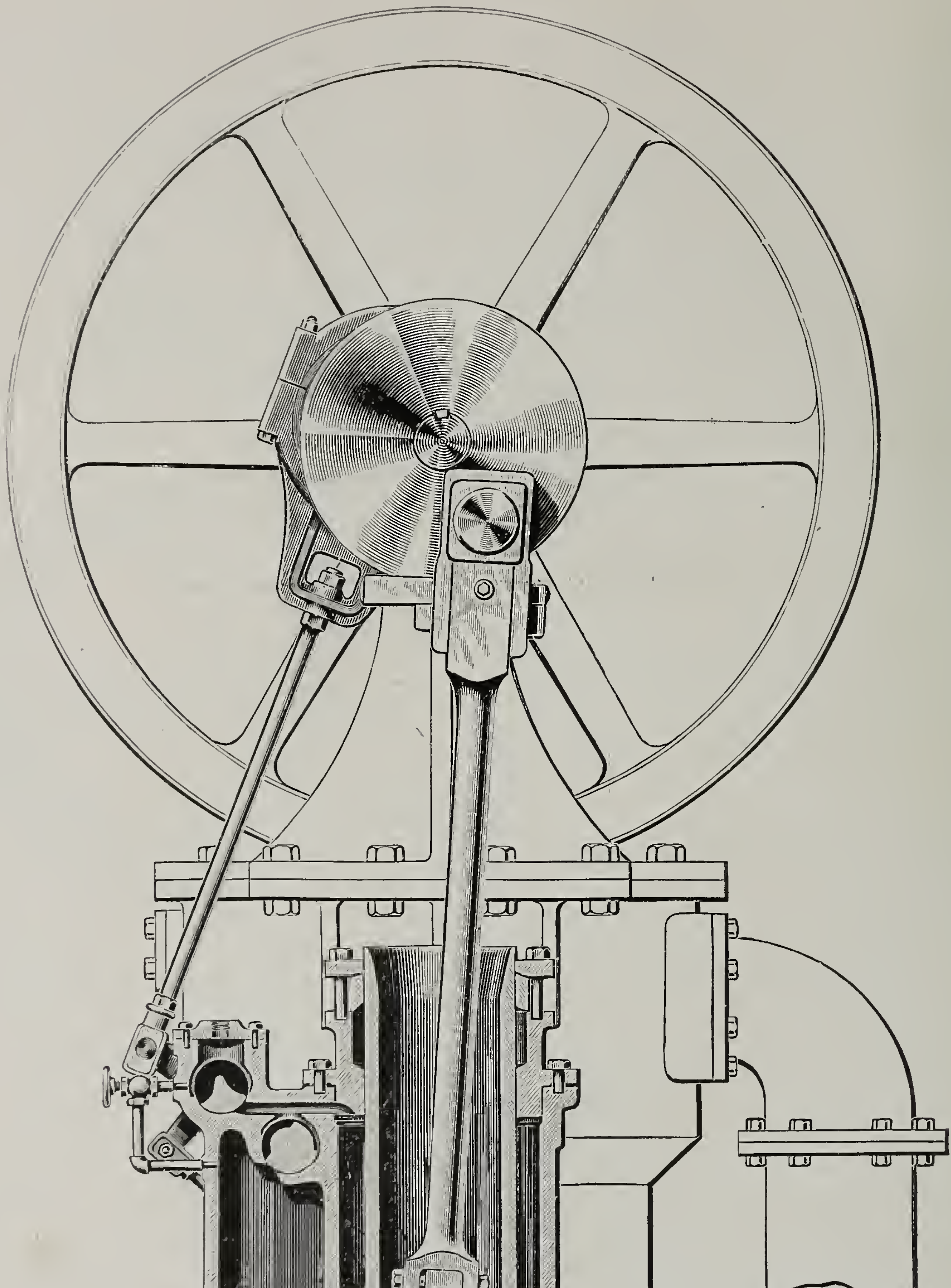
WE illustrate herewith two perspective views of a new independent steam engine condenser, made by the Conover Manufacturing Company, New York.

As a vacuum produced by the condenser is responsible for one-quarter to one-third of the entire power of the engine, it is highly important that the amount of power used to operate the condenser shall be nearly of equal efficiency with the main engine. If such is not the case, the net gain due to condensing is largely counteracted by the excessive amount of steam needed to drive the condenser. The power needed to operate a condensing apparatus is consumed entirely by the air-pump, and it is necessary, to insure good results, to have the air-pump of such design as to require the least amount of piston displacement acted on by the vacuum. With the air-pump of proper design, it is next important for best economy to have the engine driving the air-pump of such form that the consumption of steam per H.P. per hour shall approach that used by the main engine.

It is claimed for the condenser shown that the above points are fully met as nearly as it is possible to do so and not make the apparatus too cumbersome or expensive for general use. In Fig. 1 the condenser is at the right, the air-pump is at the left, and the engine is in the middle. The air-pump is vertical, and single acting, and the current of outflowing water, mixed with the air as it comes from the condenser, is always upward. It is a well-known fact that the air rises to the top, and this form of air-pump allows the air its natural tendency to rise. The air-pump is of the trunk pattern, and being vertical and having the outlets above the valves and stuffing-boxes, these necessary parts are always automatically sealed with water. The valves are of rubber, and no springs are used to hold them, as they hold to their seats by gravity alone, thereby doing away with frequent renewal of springs necessary in the horizontal style of air-pump. The trunk of the air-pump plunger is a loss of capacity, and not a loss of power, as the vacuum acts on both the upward and downward stroke, thus giving back as much as it takes. It is claimed that this style of air-pump will accomplish equal results with the horizontal, double-acting type, and with considerably less of piston displacement, —a very important feature.

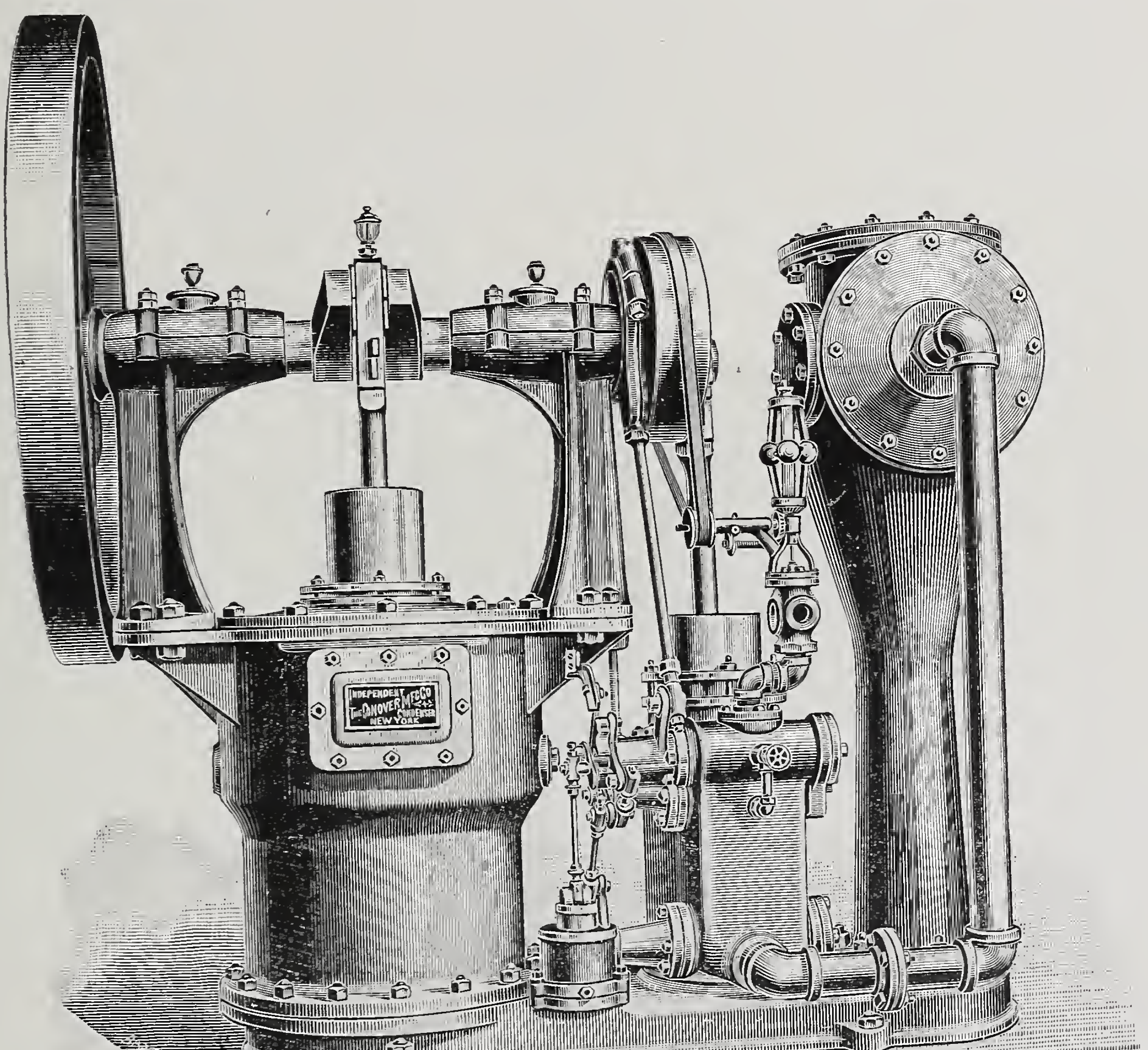
As the air-pump is single acting and does all its work on the upward stroke, and none at all on the downward stroke, the engine is made (on this condenser) to do the work on its downward stroke called for to operate the pump when making the upward stroke. The engine on its upward stroke furnishes the power necessary to keep the machine up to speed, and is ready at the beginning of the downward stroke to do its work as before. This engine is also of the trunk pattern, and is compound condensing. By referring to Fig. 3, it will be seen that the annular space around the trunk on the upper side of piston forms the high-pressure side. This upper or high-pressure side of piston is fitted with a complete Corliss valve-gear and dash-pot, adjustable with hand cut-off. A throttle governor is used to regulate the speed of air-pump, and at the same time this governor furnishes the initial pressure that is required by whatever point of cut-off that is used on the engine. The governor is also valuable to keep the machine running at regular speed, and it does not have to be adjusted for variations in the boiler pressure or changes in the quantity of injection water. The steam enters the high-pressure side and is cut off and expanded and exhausted into the receiver shown between the upper and lower valves. This receiver steam is admitted to the low-pressure side of piston by the bottom valve, which has a fixed cut-off at five-eighths stroke. It is then expanded and finally carried to condenser.

It will be seen that when the engine is making its downward stroke it has full boiler pressure on its upper side, and vacuum on the low-pressure or bottom side of piston. This vacuum



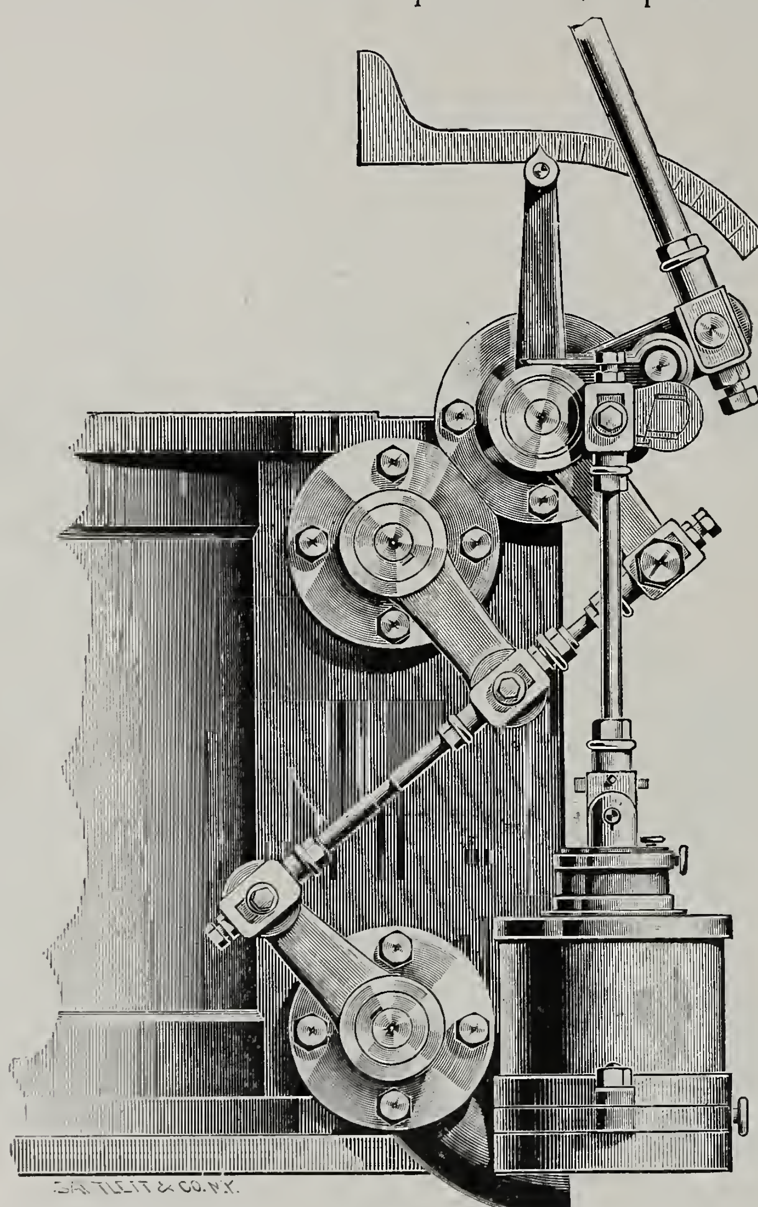
SECTIONAL VIEW OF NEW INDEPENDENT CONDENSER.

acts on the full area of the diameter of the cylinder, and in connection with the steam pressure on the top is arranged to be sufficient to cause the pump to make its upward stroke, during which it does all its work. When the pump starts to make its downward stroke, the engine is going up with the receiver pressure acting on the lower side of piston. But as the annualar space around the upper side of piston is also subjected to receiver pressure, the effective area acted on by this receiver steam is equal to the diameter of the trunk. It will be seen that the engine takes steam once every full revolution. It is practically single acting, and consequently admirably adapted to operate a single-acting air-pump. The piston is made extra deep, and thereby never exposes the top end of cylinder to the vacuum temperature of the bottom end. The engine crank-pin is not directly opposite the air-pump pin, but is set back thirty degrees. In doing this the full pressure is on the engine crank-pin at the time the air-pump is doing its heaviest work; that is, when the air-pump is half way up on its upward stroke, the engine being set back thirty degrees from directly opposite, practically has just cut off at quarter stroke, and the full boiler pressure is still on the engine; and when the air-pump reaches the top of the stroke, the engine is thirty degrees back of the bottom cylinder, and the balance-wheel



very readily throws this over past the center. And further, when the air-pump is at the bottom of its stroke the engine has not reached the upper center by thirty degrees, and the fly-wheel is called upon to throw the engine over past the dead center. By this time the air-pump has its valves thoroughly seated and the the engine is ready to do its heaviest work. From the foregoing it will be seen that comparatively small fly-wheels are needed, and that prac-

tically very little power is stored in them. A special claim is made for this condenser, that it will run without noise. There is no foot-valve at the bottom of the air-pump, as the condenser at the right acts as a water column to give the proper head, and force the overflow water through the valves in the piston, and on the return stroke of the piston this water is easily forced back slightly by the condenser, and thereby avoiding all shock. This condenser is also made

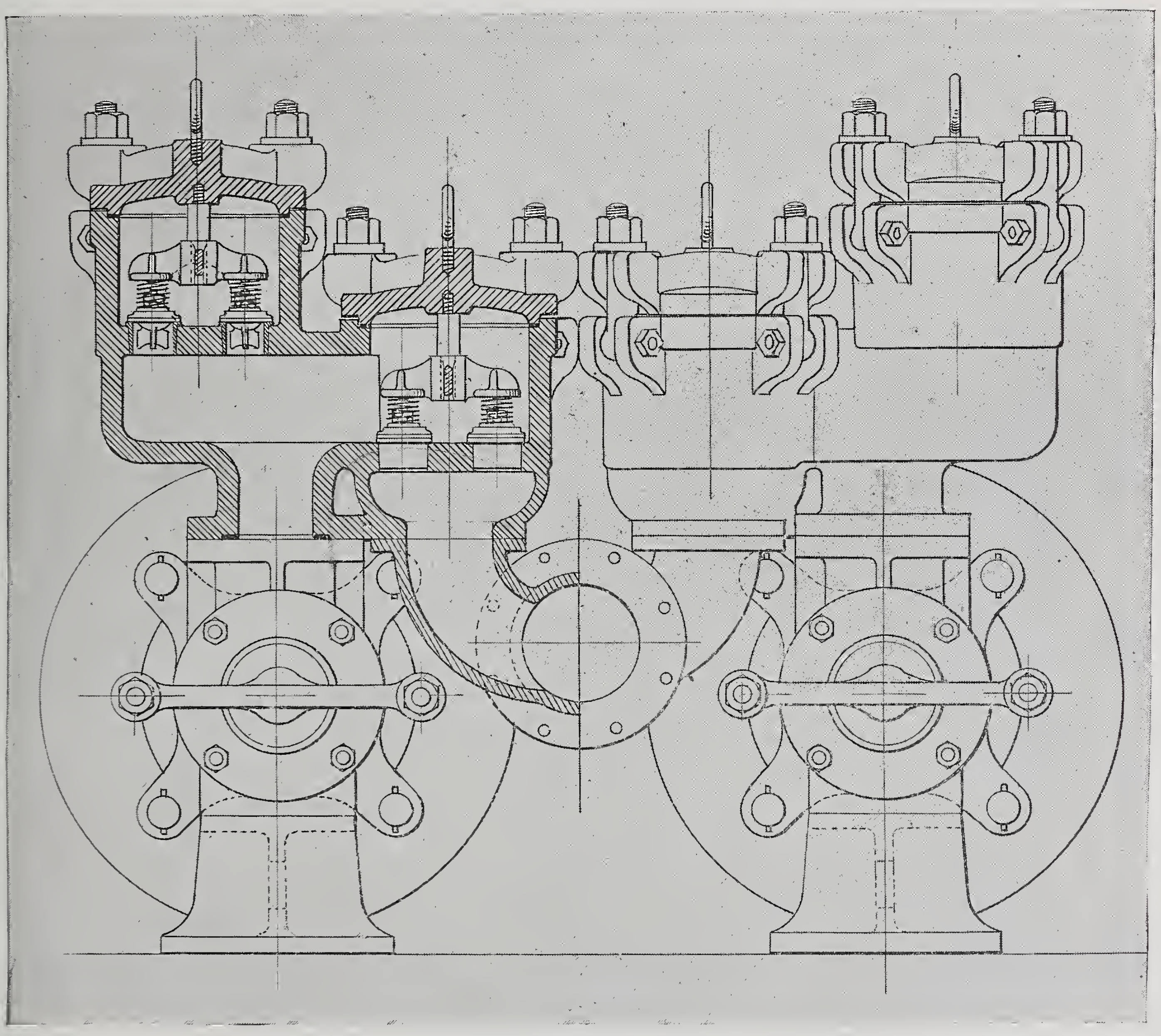


of a special form determined by experiments, and advantage is taken of the velocity imparted to the injection water due to condensation. The pumps are made very heavy and substantial, with extra large crank-pins, and bearing surfaces are intended for continuous night and day use. The air-pump is brass lined ; the plunger is a solid brass casting, and the diaphragm, stuffing-boxes, glands, studs, nuts, etc., are made of solid brass, over a ton of brass being used in a condenser of 1500 H.P. capacity. In the smaller sizes the amount of brass is about one-sixth of the total weight of the machine.

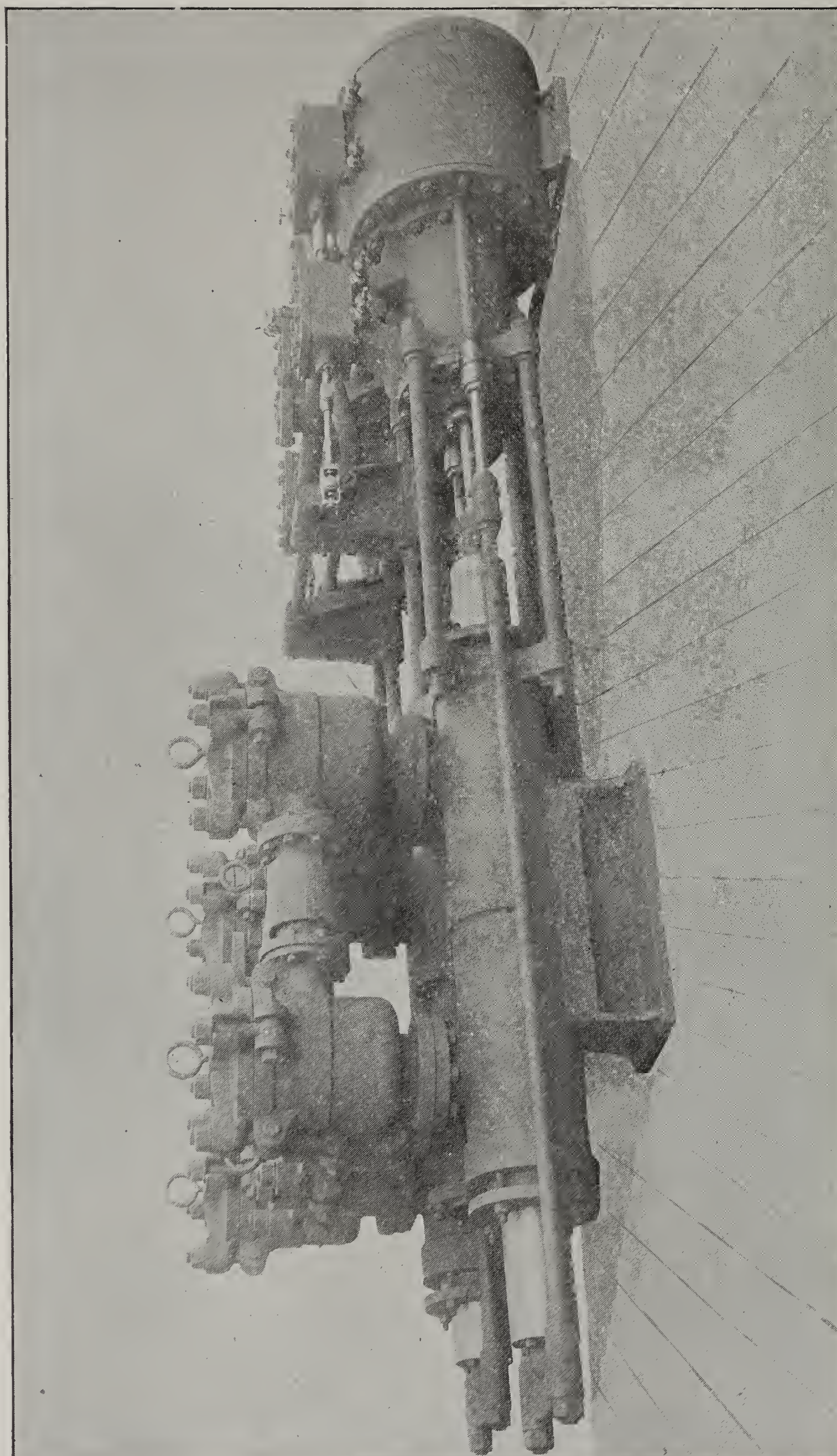
The double condenser, shown in Fig. 2, has all the special features of the single machine, but for large powers it makes a very nice arrangement, as the two single-acting air pumps are connected opposite, and give a very continuous and easy motion for very large powers. A special arrangement provides for connecting the central wheel to either pump, thereby making it possible to run either side or the entire machine at pleasure. The spray in the condensers, at the end of injection pipe, is arranged to catch all floating matter that passes the foot-valve screen. It is claimed that this arrangement is much easier to remove any foreign matter that collects in the spray than it is to allow this substance to go through the air-pump and collect in the valves.

A NEW MINE PUMP.

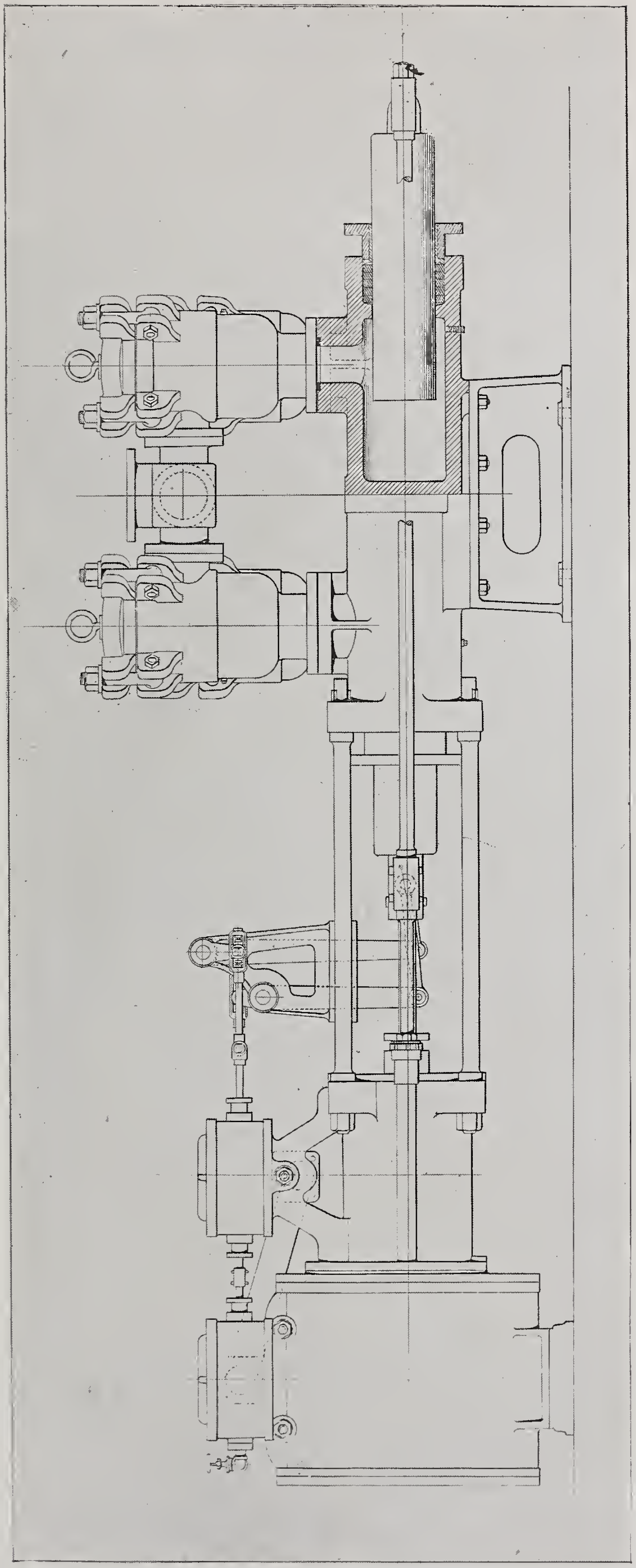
THE accompanying engravings show a new compound condensing mine pump which is built by the Buffalo Steam Pump Company, of Buffalo, N. Y. The company is now building the third of these 12 x 22 x 7 x 18 pumps for the Penokee & Gogebric Development Company, of Ironwood, Mich. These pumps range in capacity from 300 to 350 gallons per minute, delivered 600 to 700 feet high, with a steam pressure of 60 to 70 pounds. The company has built for the Chandler Iron Company, of Ely, Minn., a similar pump, 16 x 30 x 9 x 18, having a capacity of 500 gallons per minute, delivered 500 feet high. The pumps are what are known as outside packed plunger pattern. The plungers are tied together by steel tie rods fastened to cast-steel cross-heads, into which are keyed the steel piston rods of the steam cylinders. The valve chambers are of the overhead pot form, arranged for either multiple or one large single valve, as may be required. The valves and seats are made of phosphor bronze and arranged for leather facings. The covers of the valve chambers are held by swing bolts. This arrangement facilitates easy and quick access to either suction or discharge valves, which is an important feature in pumping machinery designed for mine service. The steam cylinders are arranged in duplex form, the valve of one engine being operated by the opposite.



END VIEW.



A NEW MINE PUMP. BUILT BY THE BUFFALO STEAM PUMP COMPANY, BUFFALO, N. Y.
(See preceding page).



SIDE VIEW OF A NEW MINE PUMP. BUILT BY THE BUFFALO STEAM PUMP COMPANY, BUFFALO, N. Y.
(See preceding page).

Reflections and Observations.

DURING a recent discussion concerning the value of jet propulsion for ships, as applied in the "Evolution," a prominent hydraulic engineer related one of his boyhood experiments. The experience then gained has since been worth considerable to him he says as it prevented him from risking money on any such system of navigation. When he was a lad of about twelve years, he fitted a garden force-pump into a flat bottomed punt. A piece of ordinary garden hose led from the pump to the one end of the craft where it terminated beneath the surface of the water. He had bright hopes of traveling in his boat up to Spuyten Duvel, Fort Lee and many other places along the Hudson. When everything was in readiness for the trial, he invited a schoolmate to accompany him. With fluttering hearts and hopes running high, they "shoved off" and commenced to work the pump. But do what they could it was impossible to make any headway against a three-mile-an-hour tide. To this day the then disappointed inventor can recall with the greatest vividness the sickening sensation which overcame him as he saw that his rude system of jet propulsion was a failure.

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A FRIEND of mine who is a lieutenant in the U. S. Navy relates an incident that occurred on board his ship during the time when mercury gages were extensively used on vessels. He was standing in the engine room when an oiler suddenly rushed in with consternation and alarm showing itself in all his features. "Please sir," said the oiler, "the vacuum gage is busted and the vacuum is running all over the floor!"

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THE destructive power exerted by a projectile from the 110-ton gun has been shown in an English magazine by a full-sized diagram more than 40 feet in length, which traces the path of the huge conical bullet through various obstacles, the diagram professing to be a correct representation of an effect which actually occurred. The projectile itself is depicted embedded in a mass of brick-work, into which it has penetrated 3 feet; but before finding itself at this end of its journey it has made a hole through a 20-inch steel plate, then through 8 inches of iron. Then it tore its way through 20 feet of oak timber, 5 feet of granite, and 11 feet of concrete, still having sufficient impetus to bury itself in the brick-work, as already described.

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A YEAR or two ago, about the time of the strike, at one of the Pittsburg iron works the feeling against Pinkerton detectives was very great, and when one was supposed to be about every effort was made to find him and make him leave the locality. One of the pickets employed by the men learned that a detective was near-by. The men became frantic, and rushed hither and thither in their efforts to locate the man. The crowd grew larger and larger every minute.

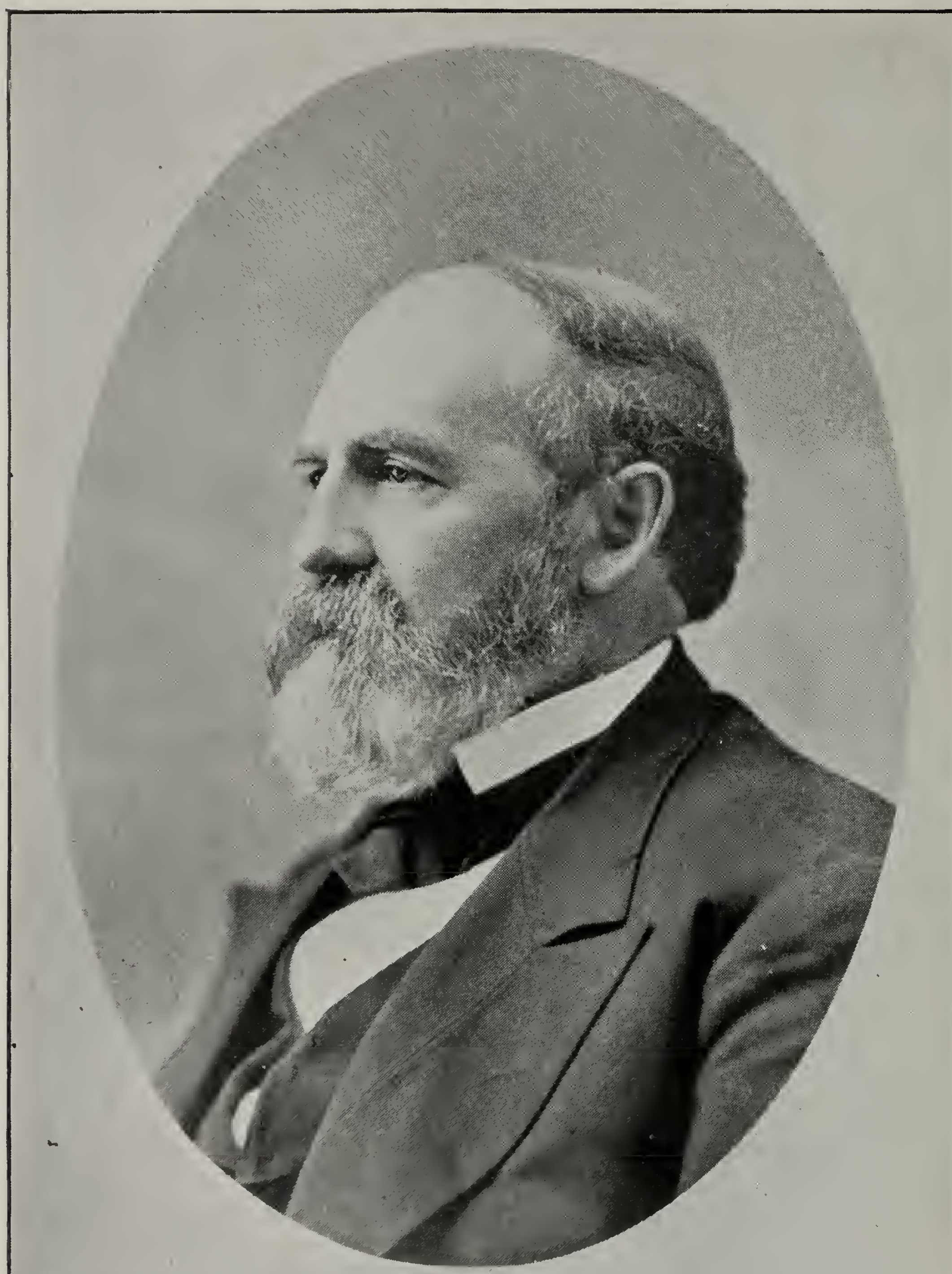
"Find him," "find him!" was the cry.

The Allegheny river is near-by, and "Throw him in the river," "Down with him!" and similar cries, made it plain that if the Pinkerton man was found it would go hard with him.

The detective saw the danger he was in and joined with the strikers.

"I know him," he cried, "and we'll drown him."

"Good, good!" shouted the men, so that under the cover of his zeal he escaped. It might be added that he resigned his position when he reached the city.



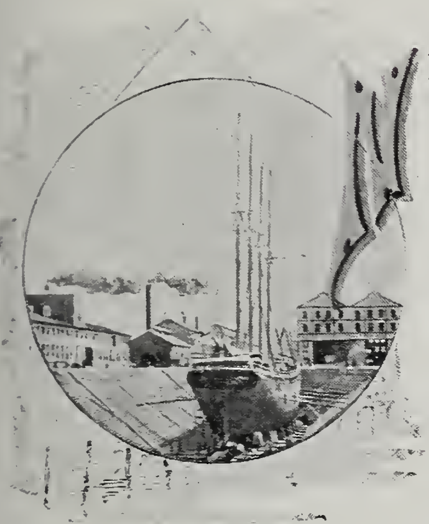
C P Huntington

CASSIER'S MAGAZINE.

VOL. II. JULY, 1892. NO. 9.

SHIPBUILDING IN AMERICA.

By Wm. H. Wiley, C.E.



NEWPORT NEWS will always be known from the naval battle which occurred there in the early history of the civil war; at that time it was an uninhabited place, and the combat was a brief one, although marked by many deeds of heroism. The fact that it was the first instance where an ironclad had attacked wooden vessels, and as such marked a distinct era in naval warfare for the world at large, revolutionizing naval armament, is what has caused Newport News to be of world-wide fame. A witty and illustrious friend of the writer once told him that he would not be known to posterity as a man who had risen to the rank of major-general during the war, nor as an engineer officer of repute, nor as a successful professor at a celebrated government school, but simply as the father of the captain of the foot-ball team of that institution. So while the world at large knows Newport News from an important battle, but few know the Newport News and its great ship-yard of the present day.

The writer, who was at Newport News shortly after the naval fight with Burnside's corps, remembers it well, and when he visited it for the first time since those days and found a city had sprung up, industries had been established, and a general air of prosperity was visible around, it seemed as if the past was only a vision. One year later another visit was made, and then it seemed as though some magician had transformed the whole face of the country. Indeed, so rapid had been the growth, that if the visitor of the year previous had been transported there unconsciously he would hardly have known where he was. Change after change has taken place, always in the line of progress, till to-day the visitor looks at a city of nearly ten thousand inhabitants, with a fine hotel, excellent schools, and, in fact, all the accessories of modern civilization. A glance at the map (see Fig. 1) shows the location of this spot to be about in the center of the Atlantic coast line. It is situated on the southerly point of the peninsula lying between the James river and Chesapeake bay, that peninsula so marked by the fierce struggles of the war, so many of which occurred within a radius of fifty miles.

Hampton Roads, which lies below, is an ideal harbor, completely landlocked, and with a deep, broad channel of ample depth of water at all seasons. It is usually very quiet and peaceful, but on the occasion of the writer's last visit its broad bosom was evidently very much ruffled by the presence of a large number of members of Congress, some of whom had been active in cutting down the naval ap-

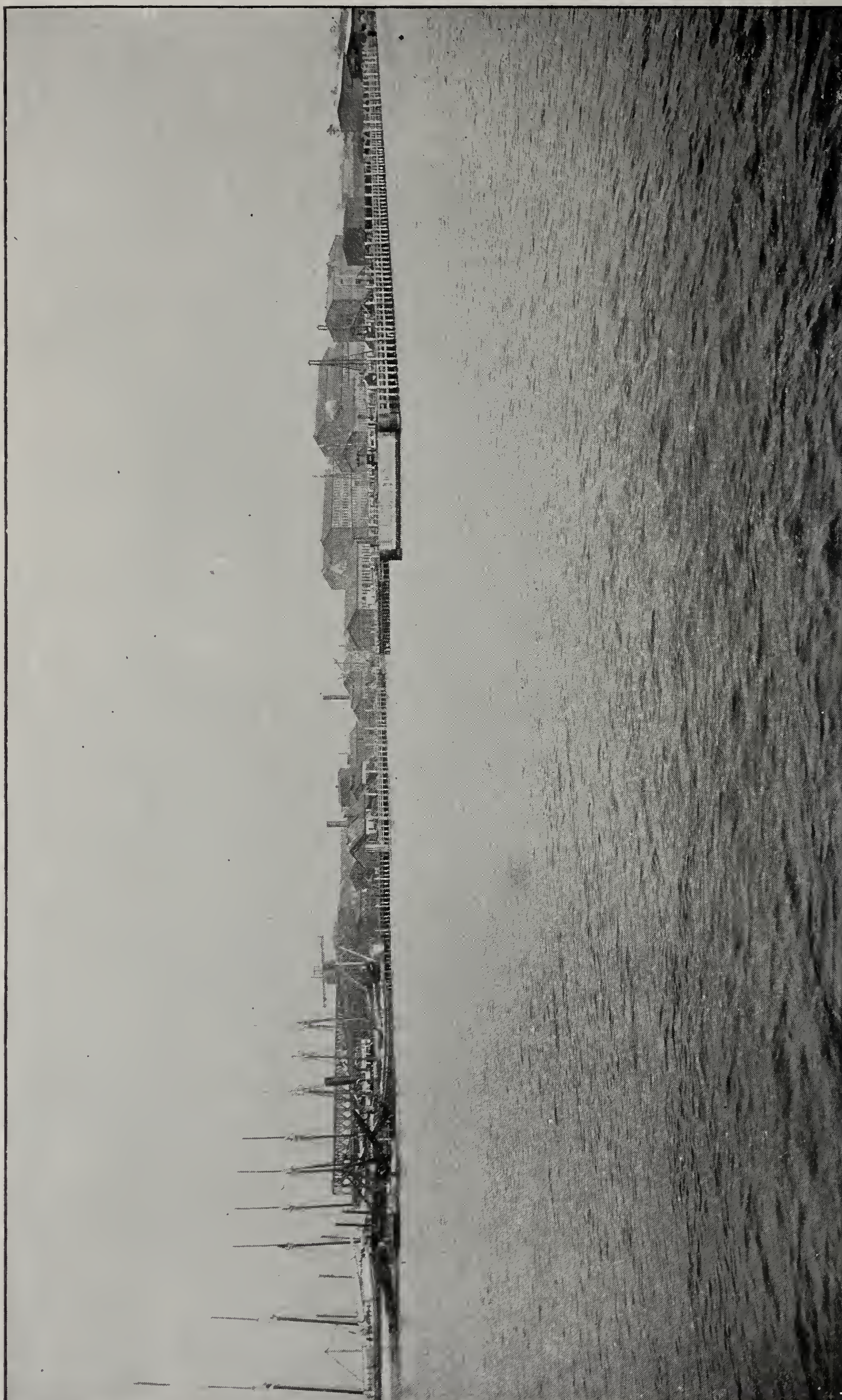


FIG. 2. NEWPORT NEWS FROM THE HARBOR.

propriations, and it took signal revenge on some of them after they left Fortress Monroe, making them pay that tribute to Neptune from their inner consciousness which they denied it from the government treasury. From Hampton Roads to the open ocean, between Capes Charles and Henry, is direct and easy for the largest ships, while immediately in front of Newport News there is great depth of water with broad channels of approach.

Collis P. Huntington, the originator, principal owner, and master spirit of the great ship-yard and dry-dock enterprise at Newport News, is a Connecticut man, having been born in Harwinton, October 22, 1821, the fifth of nine children.

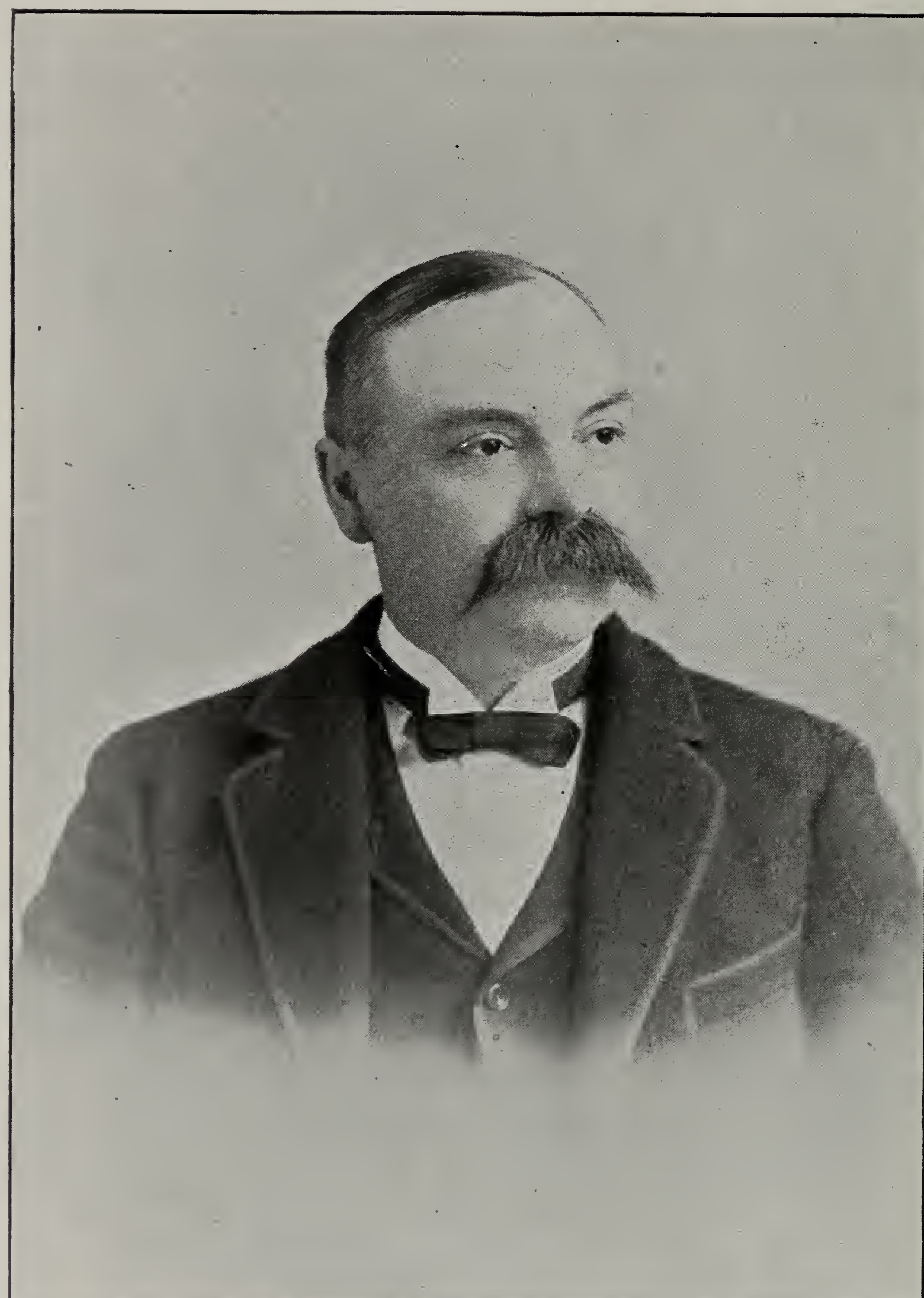
The history of his whole life is a narrative of extraordinary financial achievements, and a noteworthy exemplification of the saying that "Peace hath her victories no less renowned than war."

His business career began when he left school, at the age of 14, to work on a farm one year for $84 and his board. When a boy at that age saves every penny of a whole year's earnings, as did young Huntington, in order that he may have capital upon which to build his future fortune, one need not take the trouble to make the easy prediction of his financial success. When one sees united to this indomitable thrift and broad and quick intelligence; a tireless energy and unbounded faith in his ability to do the things that he feels ought to, and therefore can be done; with the courage and daring to act instantly and powerfully upon his convictions; and, finally, with an extraordinary capacity for patient waiting, there is formed in one individual a combine of qualities that is bound to place him among the world's celebrities.

Within the limits of this article, even the mere list of Mr. Huntington's achievements in industrial and financial enterprise cannot be recited, but it may be briefly said that after a varied and active experience as a young man in the selling of goods all through the South, he formed a partnership with his brother, Solon Huntington, in the dry-goods business at Oneonta, Otsego Co., New York, and remained there until he was 21 years of age. Then came the stirring reports of great gold discoveries in California. The fever and excitement awakened by them penetrated even to this quiet town, and young Huntington, who had long been dissatisfied with the opportunities for making money afforded by so small a field as Oneonta, determined to try his chances in the new El Dorado; but he was in no sense "gold-crazy," for his rare discernment pictured to him greater profits in the line of legitimate trading than in the irregular and dubious outcome of gold-hunting. On March 15, 1849, he sailed for the Isthmus on the steamer *Crescent City*, and it is typical of the character and force of the man that during his enforced stay in the inhospitable and unfamiliar country he succeeded in adding several thousand dollars to the capital he had brought with him. Arriving at last at San Francisco, he left his companions of the voyage at the different hostelries, and started for Sacramento. There he soon formed a partnership with Mark Hopkins in the hardware and metal business, and laid the foundation to a vast fortune.

The story of the inception of the Central Pacific Railway, of the vicissitudes of its construction, and financial struggles, and of its final successful completion, are too well known to need recital. The Southern Pacific from San Francisco to New Orleans—2500 miles in length—followed, and in the meantime the great railroad enterprises in the East were being conceived and carried out. The Chesapeake & Ohio, the Louisville, New Orleans & Texas, the Chesapeake, Ohio & Southwestern, the Kentucky Central, and numerous smaller roads or branches, represented the restless activity of this indefatigable worker. The great organizations under his control have steadily grown in number. The genius of Mr. Huntington is essentially operative. He has been a builder all his life, and it may be truly said of him that development has ever followed his footsteps.

Many years ago, Mr. Huntington, in the midst of his multitudinous cares, had time to study the possibilities of Newport News, when its site was a wilderness. He early perceived the true value of the advantages offered by this



C. B. Orcutt

port at Hampton Roads as a deep-water terminus for the C. & O. Railway. In conjunction with a few others the land was acquired and the work of building a city was begun. From the first day of his purchase, Mr. Huntington has liked to repeat with great emphasis that Newport News is "the best half acre in the world." He has discouraged any "boom" of the town, preferring to let the place have a natural and solid development. His latest achievement—the establishment of the great shipyard and dry dock at the port—was one that would have astonished by its magnitude any one not familiar with the dominant nature and assertive courage of the man ; and that it should have been made the largest and most completely equipped establishment in the world, is in the direct line of that ambition which has never been satisfied with less than the best.

Associated with Mr. Huntington is Calvin B. Orcutt, who is his lieutenant, being president of the company ; Sommers N. Smith, the general superintendent ; Horace See, as consulting engineer, and I. E. Gates, treasurer.

Mr. Orcutt, who is president of the company, was born in Wyoming, N. Y., September 5, 1847. His parents were New Englanders, in well-to-do circumstances, when financial reverses, during the panic of 1857, swept away their possessions, making life a struggle for them thereafter. Owing to this fact, young Orcutt was obliged to forego the advantages of a collegiate education, and in 1862, after having been well tutored at Middlebury Academy, in Western New York, moved to Jersey City, N. J., with his parents, and after a year's study in No. 3 High School of that city, commenced his business career in the wholesale drug business in New York. One of the first duties he was assigned was to clean the office windows ; while not a particularly congenial occupation, he cleaned them well, and by faithful service was enabled to earn enough money to not only care for himself, but contribute to the support of the family.

Not finding the drug business to his taste, he looked around for a better occupation, which, in time, was secured, and in 1864 he entered the banking office of Fisk & Hatch, the well-known firm, then located at 38 Wall Street, in whose service he remained for 14 years, gaining valuable business knowledge, and becoming acquainted with a number of merchants and railroad men, who who were of great assistance to him in later years. In 1878 the Chesapeake & Ohio Railway Co. sought a tide-water outlet for its coal, and Mr. Orcutt was placed in charge of marketing the coal, and shipping same to coastwise ports ; the product being first loaded into vessels at Richmond, Va., and later at Newport News. The business has grown to large proportions, and is still managed by Mr. Orcutt. In connection with this work frequent visits to Newport News were made necessary, and so it came to pass that Mr. Orcutt was placed in charge of Mr. Huntington's numerous interests at that point. Under his management, as president of the Old Dominion Land Co., whose capital is $2,000,000, Mr. Orcutt has had the great satisfaction of seeing Newport News grow from a little hamlet to a town of 7000 souls.

Commissioned by his chief, Mr. Huntington, who tendered to him the presidency of the Newport News Shipbuilding & Dry Dock Co., to place at Newport News the finest shipbuilding plant in the world, he personally contracted for all of the buildings and machinery comprising its immense plant. After visiting ship-yards in the United States and gathering full information respecting those abroad, he counselled with competent engineers, and then laid out the works with a view of convenient handling of material and economical operation. Banking capital being needed in the new town, Mr. Orcutt secured from his friends the requisite funds, and organized the First National Bank of Newport News, with a capital of $100,000, of which institution he is a director. He is also president of the Newport News Light and Water Co., capital $1,000,000, the construction of whose works he has been overlooking for the past six months in connection with his other duties. Mr. Orcutt lays no claims to genius, but looks for success through patient industry and frugal habits.

FIG. 4. TRAVELING CRANE.

The general view of the shipbuilding works as seen from the harbor is shown in Fig. 2. On the extreme left are the building-ways with their cantilever crane, and next the various shops of the company with the entrance to the dry dock in the center of the picture.

There are two building-ways, 500 feet long, and the crane extends over both, thus facilitating the work to a very great extent ; in fact, close observation of the entire plant will show that an effort has been successfully made to reduce all manual labor to a minimum, and further, to handle material as little as possible. As an evidence of this success it may be stated that four men laid the keel for a ship nearly 500 feet long in four hours, and when the *El Sud* was launched from one of these ways a few months ago, the visitors, having witnessed the magnificent spectacle and enjoyed a fine lunch, were invited to return to the way, where they found the keel to a steel ship already partially laid during their absence at the meal. It must be said that this was not one of the old Roman type of banquets, which continued for days, but simply an elegant repast lasting some three hours. The view of the ways used for the *El Sud*, as above noted, is shown in Fig. 3, and that ship so successfully launched last month in the presence of thousands may be distinctly seen at an early stage of construction. The traveling crane is also to be noted, but a better view of it is shown in Fig. 4, and the decks of the two ships are seen on the right and left hand, *El Sud* being on the right. In addition to these ways, there are two others of 400 feet each and two of 450 feet each, also, with a traveling crane, and two of 600 feet.

The illustrations give but a faint idea of the immense establishment, which is composed of the following buildings :

	Feet.
Office building, three stories, brick	40 x 200
Pattern and joiner shop, three stories, brick	60 x 300
Machine shop, iron and brick	100 x 300
Boiler shop, iron and brick	100 x 300
Blacksmith shop, brick	100 x 300
Bending shed, iron and brick	60 x 127
Ship-fitters' shop, iron and brick	60 x 320
Ship blacksmith shop, frame	120 x 208
Pipe-fitters' shop, frame	50 x 208
Power house, brick	40 x 130
Lumber shed, two stories, frame	40 x 300
Pump-house, brick	43 x 60
Paint shop, brick	50 x 160
Stable, two stories, brick	40 x 60
Timekeeper's house, frame	50 x 40
Fitting-up shop, brick	50 x 175

PIERS.

No. 1	60 x 900
No. 2	60 x 350
No. 3	80 x 350
No. 4	60 x 550
Outfitting basin	900 x 500

SHIP-WAYS.

	Feet long.
No. 1	400
No. 2	400
No. 3	450
No. 4	450
Nos. 5, 6, 7, and 8, each	500

Whoever planned this yard is deserving of great credit, for the various buildings are so arranged that the construction is progressive without breaking the continuity. In other words, the pieces under construction having gone through one shop pass to the one *nearest* in their journey toward completion, and the arrangement, to use a common simile, is like a game of progressive euchre, the completed piece having its final touches put on it at the shop nearest the place of erection. To illustrate, after the design for the hull has taken shape in the brain of the engineers it gets worked out as to details in the drafting-room, located near the entrance ; from here the drawings go to the molding loft, which is said to be one of the largest in existence, being 306 x 60 ft. The material necessary to the design is sent to the bending shop and there shaped, then to the beam-welding department, where the knees are welded to the beams. Meantime the plates have been marked and punched, or planed, in the ship shed. In the framing shed the frames are brought together and riveted to the floor-plates and beams by the hydraulic riveter, shown on another page ; this being done, the parts are lifted by the hydraulic crane, put in a transfer car, and taken across the yard to the ways where needed, when the cantilever crane places them in the exact part of the ship under construction where they are designed to go.

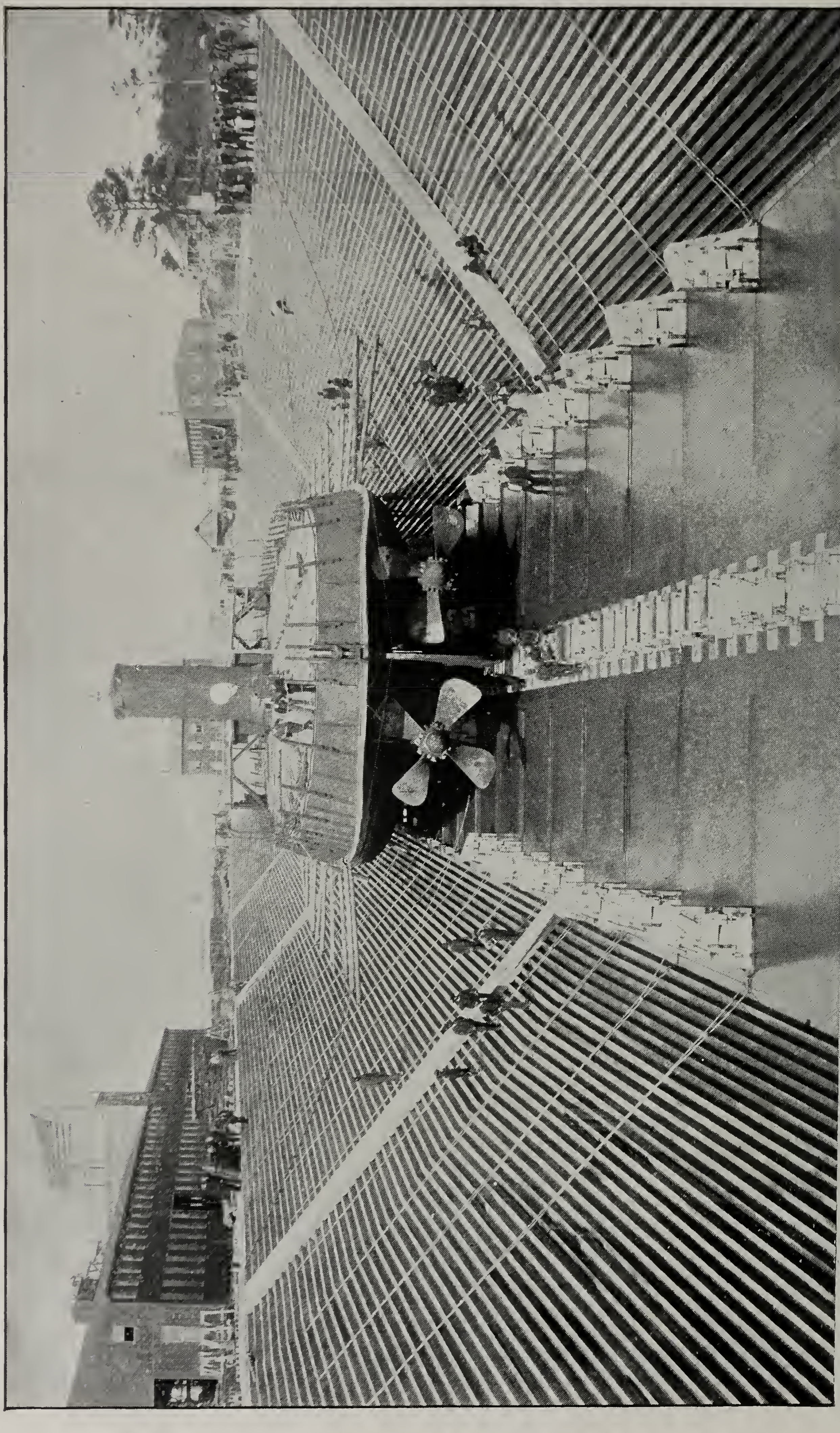


FIG. 6. DRY DOCK.

One of the most important parts of a shipbuilding plant is its dry dock, for the capacity of this to earn money seems almost unlimited, as any steamship company who has to pay for its use will readily admit. Ships are continually responsibility for the act may be fixed, its effect is to always create an emergency, and the sooner the ship is put into working order the better for her owners. The writer does not mean to say that dry-dock owners take advan-

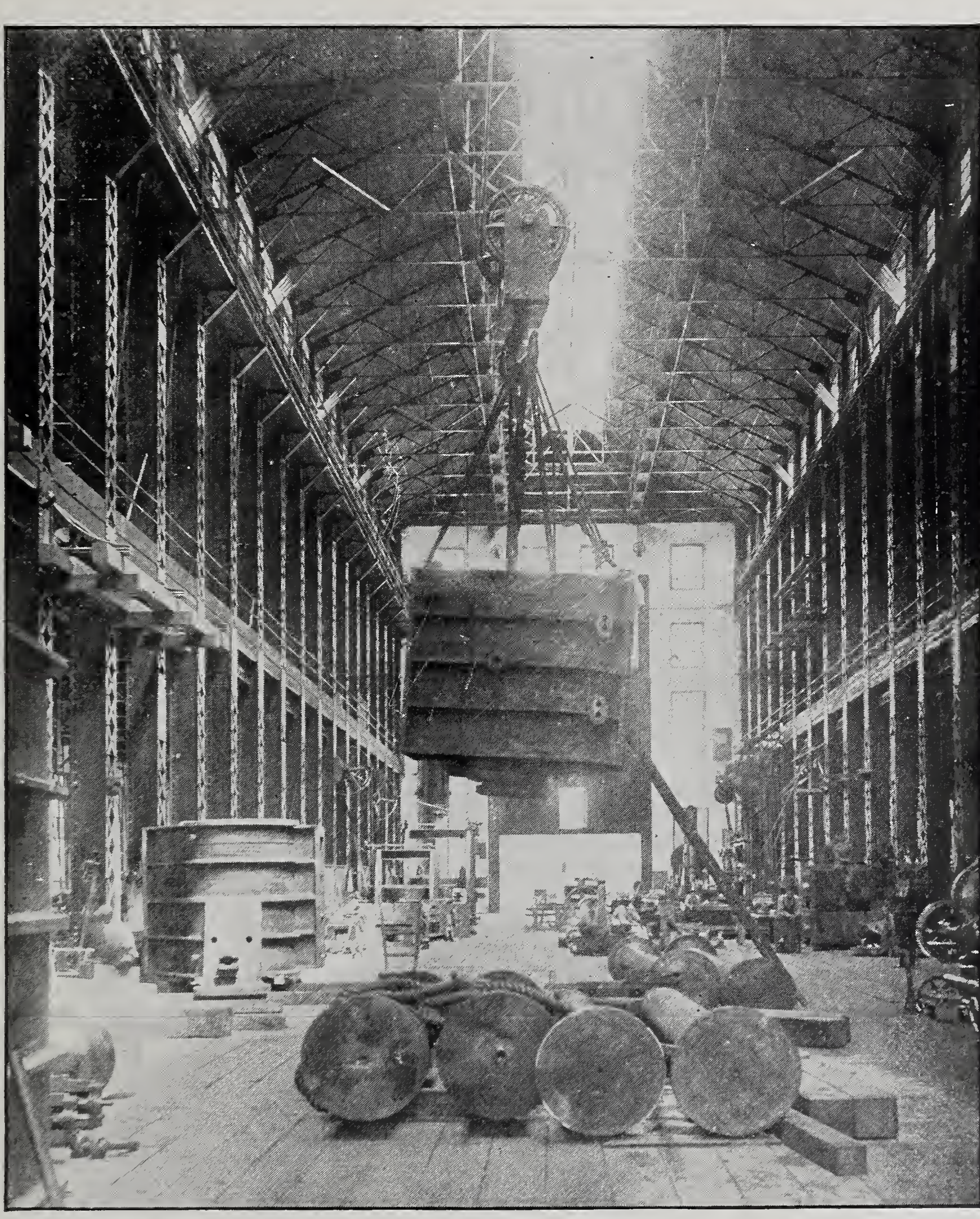


FIG. 7. TRAVELING CRANE.

breaking down, either from the battering of the elements or from bad seamanship or bad construction. All these causes combined may bring about the catastrophe, and it is usually described as an "act of God," but wherever the tage of the situation, but they must necessarily become somewhat used to vessels in distress, and may be just a little callous as to their condition and, perhaps, a little careless as to their charges; but be that as it may, dry docks are

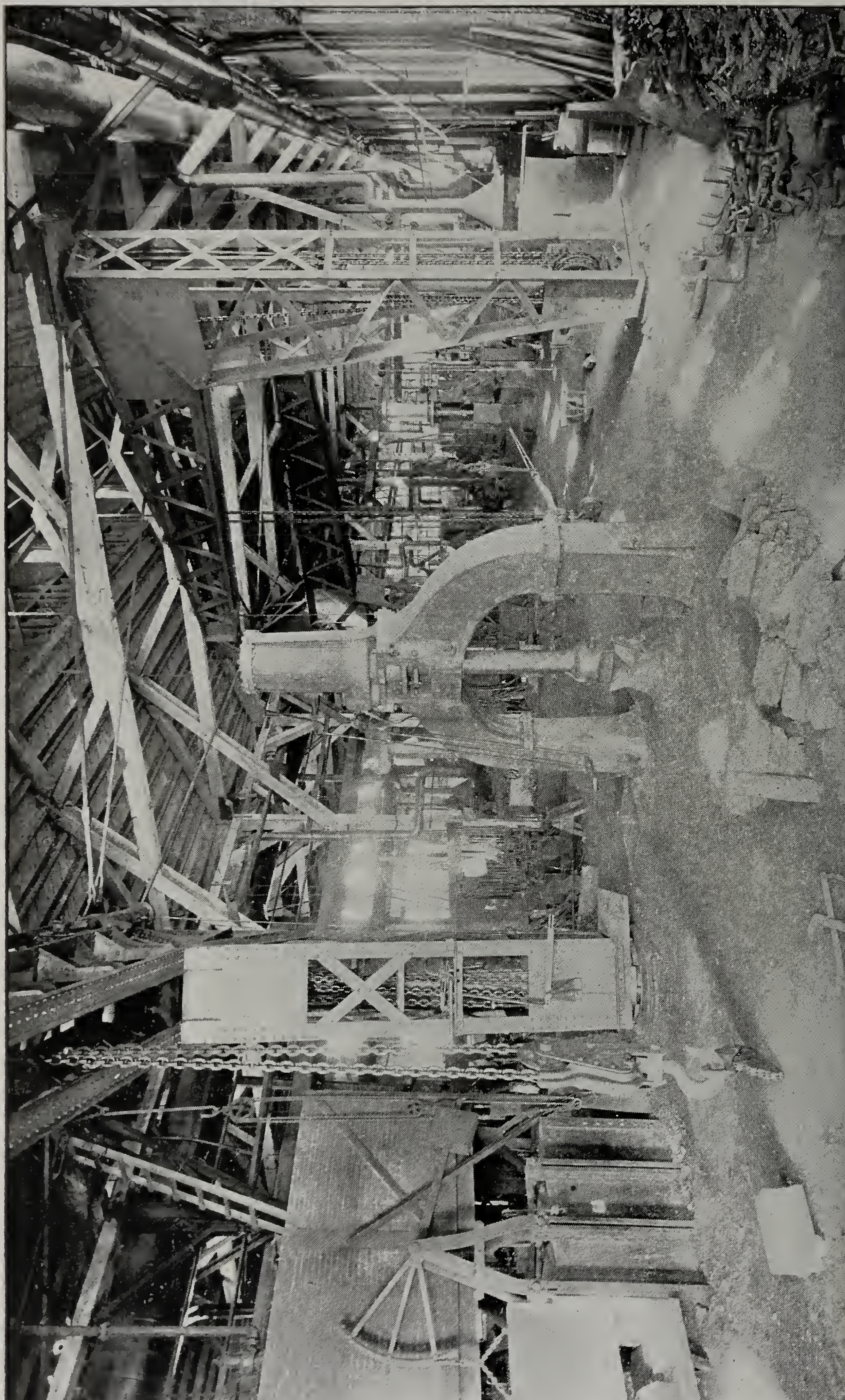


FIG. 13. THE FORGING SHOP.

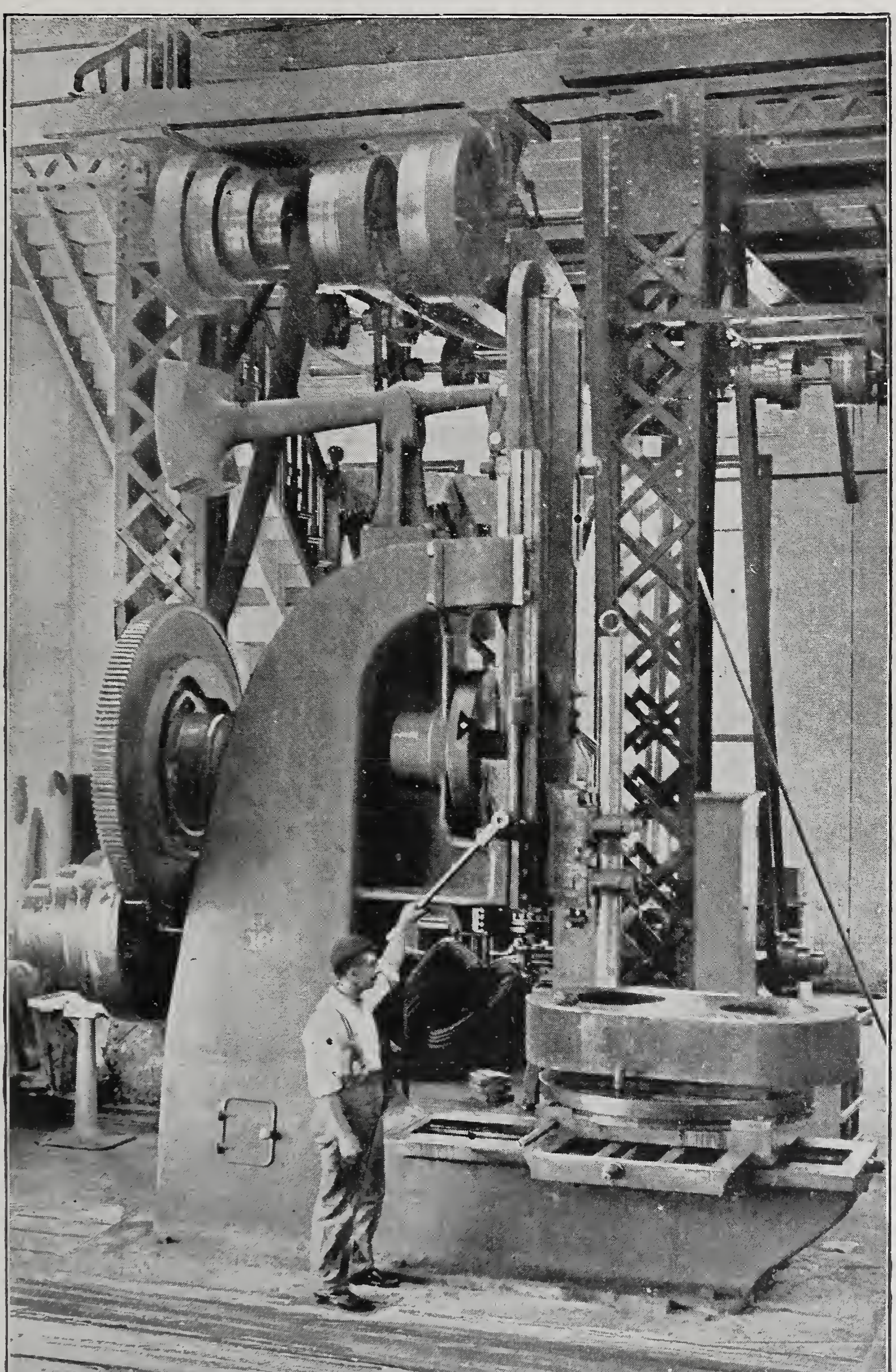


FIG. 15. 24-INCH SLOTTING MACHINE, MANUFACTURED BY BEMENT, MILES & CO., PHILADELPHIA, PA.

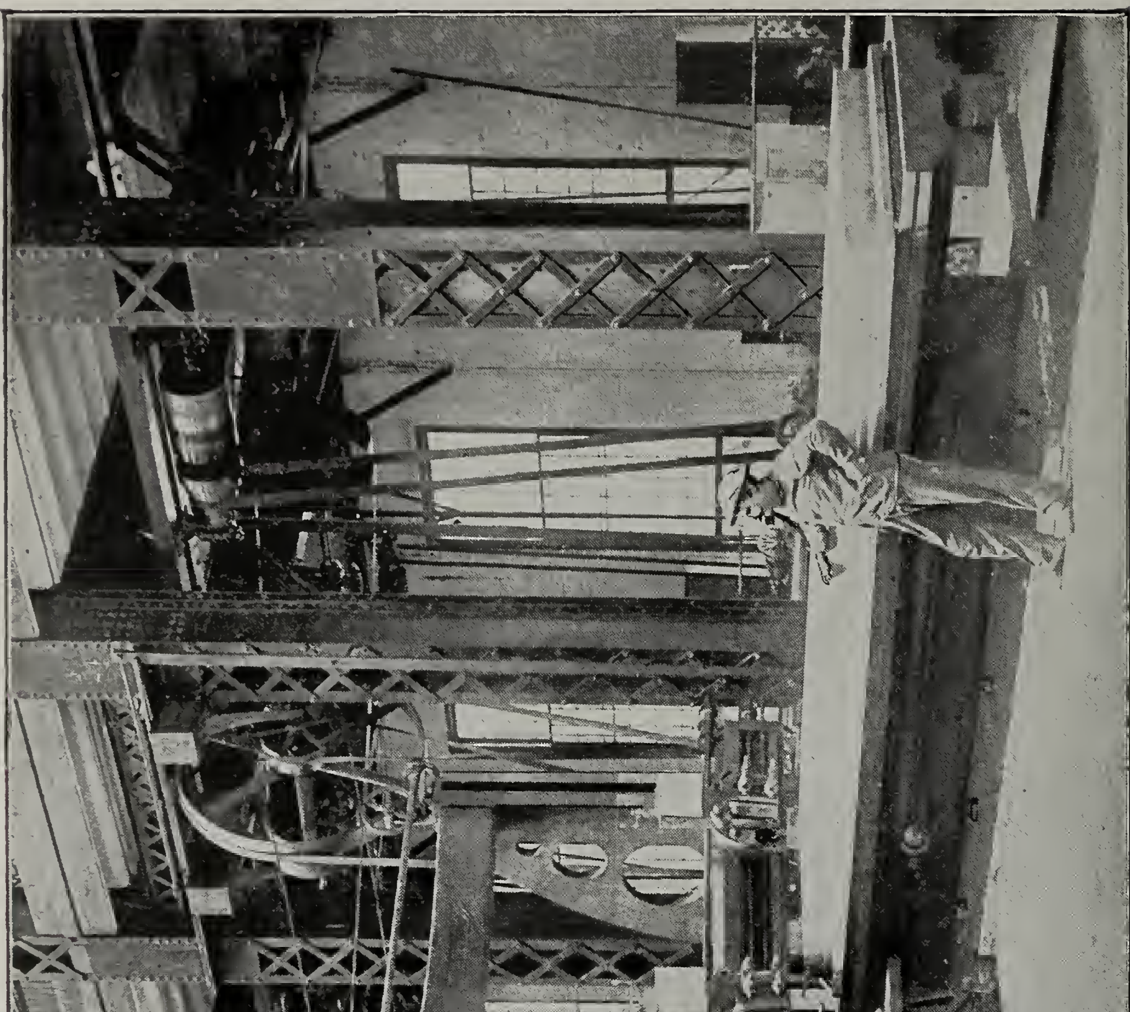


FIG. 10. 84-INCH PLANER, MANUFACTURED BY WILLIAM SELLERS & CO., PHILADELPHIA, PA.

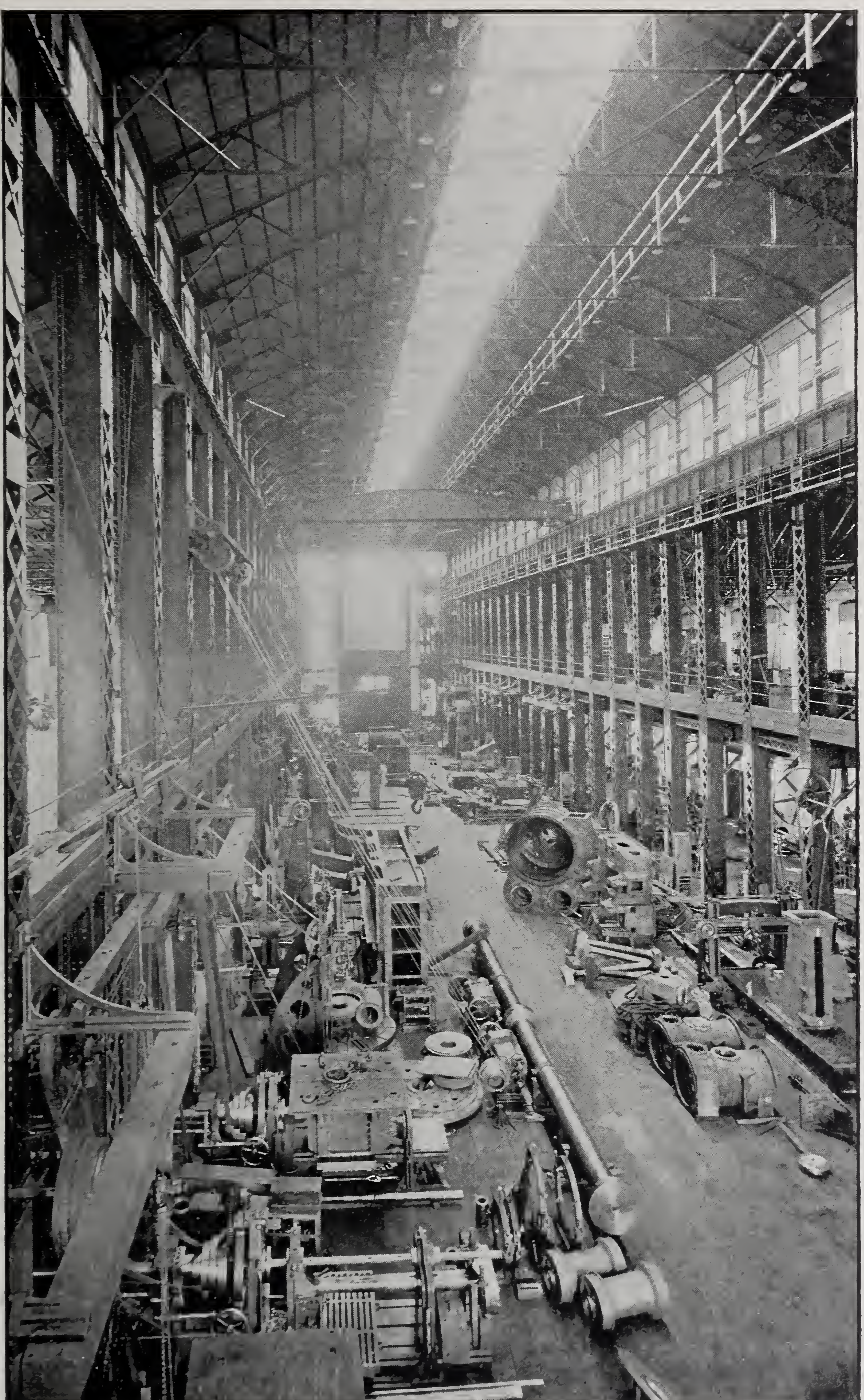


FIG. 14. BOILER SHOP.

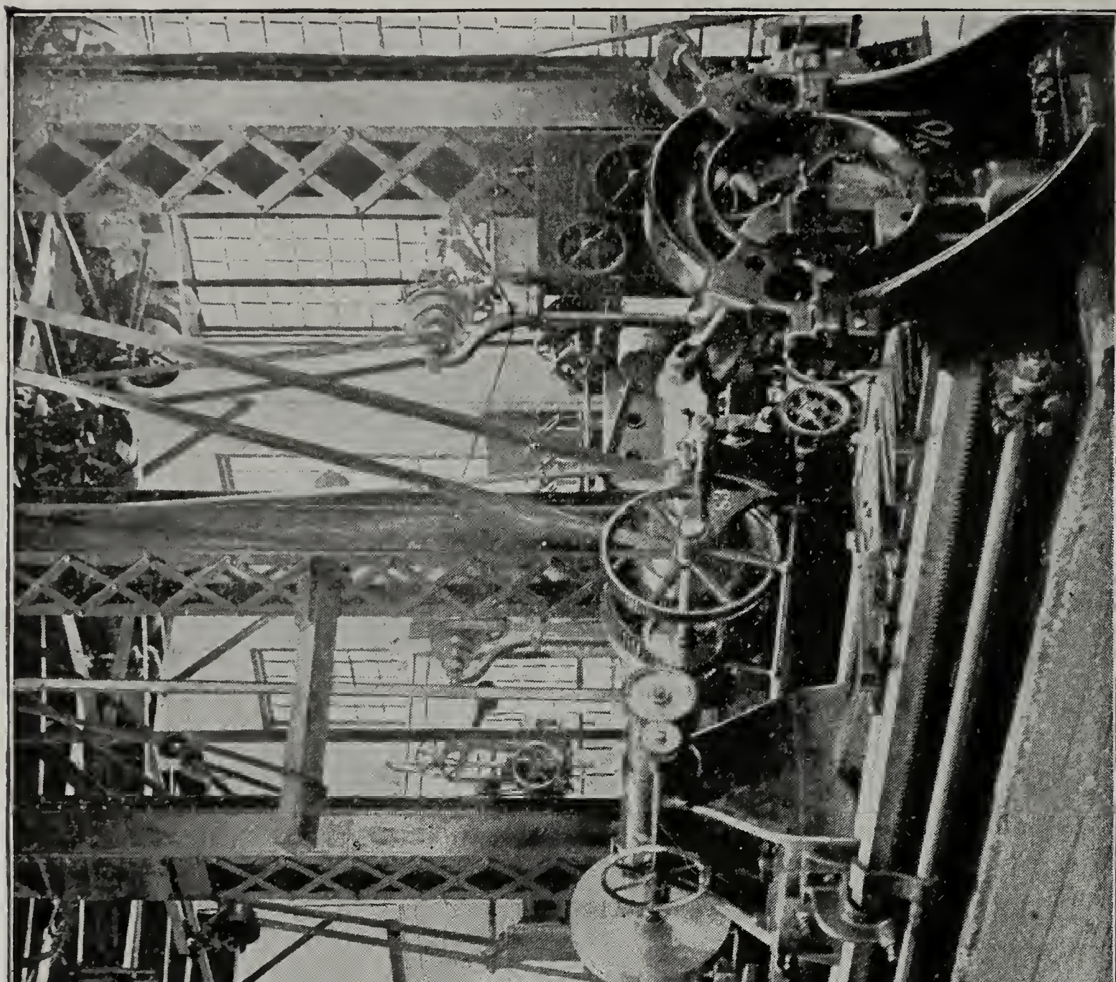


FIG. 9. 63-INCH SCREW-CUTTING LATHE, MANUFACTURED BY BEMENT, MILES & CO., PHILADELPHIA, PA.

seldom empty, and it is essential, then, that they should be large, well equipped, and capable of speedy work. All these conditions are fulfilled by the one shown in Fig. 6; and as evidence of its need it has docked over 100 vessels in a year, and, no doubt, "docked" the companies in a proper manner. It was built for this company by one of the best and most celebrated firms of dock builders in the United States, J. E. Simpson & Co., who have also made many other fine docks, notably those built for the United States government at the Brooklyn and Norfolk navy yards.

Its dimensions are:

Length on top	600 feet.
Width " "	130 "
Width on bottom	50 "
Width at entrance	93 "
Draft of water over sill	25 "
Time required for emptying dock,	1½ hours.

It was built in the very best manner, and the foundations are so well laid that the settling is considered as nothing. At the time this picture was made the monitor *Puritan* was in the dock.

The illustrations show the interior of the buildings and dock better than words can describe them. Fig. 7 illustrates the interior of the machine shop, and the tools are seen to be massive, besides being of the best design and manufacture. The visitor notes at once the light and airy character of the place. The first story has the large tools, while the second floor is fitted up with the smaller ones adapted for finishing Space will only permit the description of a few special tools in these various shops. One of the most important, however, is the traveling crane, capable of lifting some 40 tons. In the picture of the machine shop (Fig. 7) it can be seen at rest, near the roof of the building, but in these busy places there is little time for idleness, and in Fig. 8 a view of its work is shown, the crane itself having modestly retired from the focus, and leaving its work to speak for it, just as many an engineer is forced to do, but fortunately seldom in vain.

A large screw-cutting lathe of 63″ swing is shown in Fig. 9. This magnificent tool, so complete and satisfactory, comes from the celebrated firm of Bement, Miles & Co., Philadelphia, and many other tools in these shops are from the same source. Since this one was put in, another from the same firm has been added of 120″ swing.

Fig. 10 shows a tool made by a firm widely known in this country and elsewhere for their liberality and careful methods of construction, and whose shops have furnished not only some of the largest tools built, but also some of the most delicate and intricate ones; the firm is that of William Sellers & Co., of Philadelphia, and the machine shown in this connection is one of their 84″ planers, which has given satisfactory service here from the outset.

In Fig. 11 there is shown a machine for scarping ship-plates, made by Pedrick & Ayer. It has, as may be seen, two cutting-heads.

Another evidence of massive work is seen in Fig. 12, illustrating a large cylinder-boring machine, made by Sellers & Co., having a range in boring from 18″ to 108″, which last ought to satisfy even the canny Scot who declared you couldn't get an idea into a man's head by boring it.

A wall-planer is now being erected in the machine shop, which will be the first of its kind built in this country, and will be much larger than the one already described. This comes from the shop of Bement, Miles & Co.

It may be stated here that this company will shortly add to its extensive line of machinery a large plate-bending machine, capable of bending ship-plates 32 feet long; this will be by far the longest set of ship-plate rolls in America, and will be put in with a view of following best practices abroad in respect to using long plates.

In Fig. 13 is shown the smith shop, which is a brick structure of 100′ x 300′, equipped with numerous hammers ranging from 600 pounds to 6000 pounds, and is also fitted with hydraulic jib-cranes of 20 tons capacity and less. The hammer in the foreground is a 3-ton hammer and is extremely useful and always busy.

In Fig. 14 the reader may see the interior of the boiler shop. This, too, is light and airy, and its walls and ventilating arrangements are guaranteed to

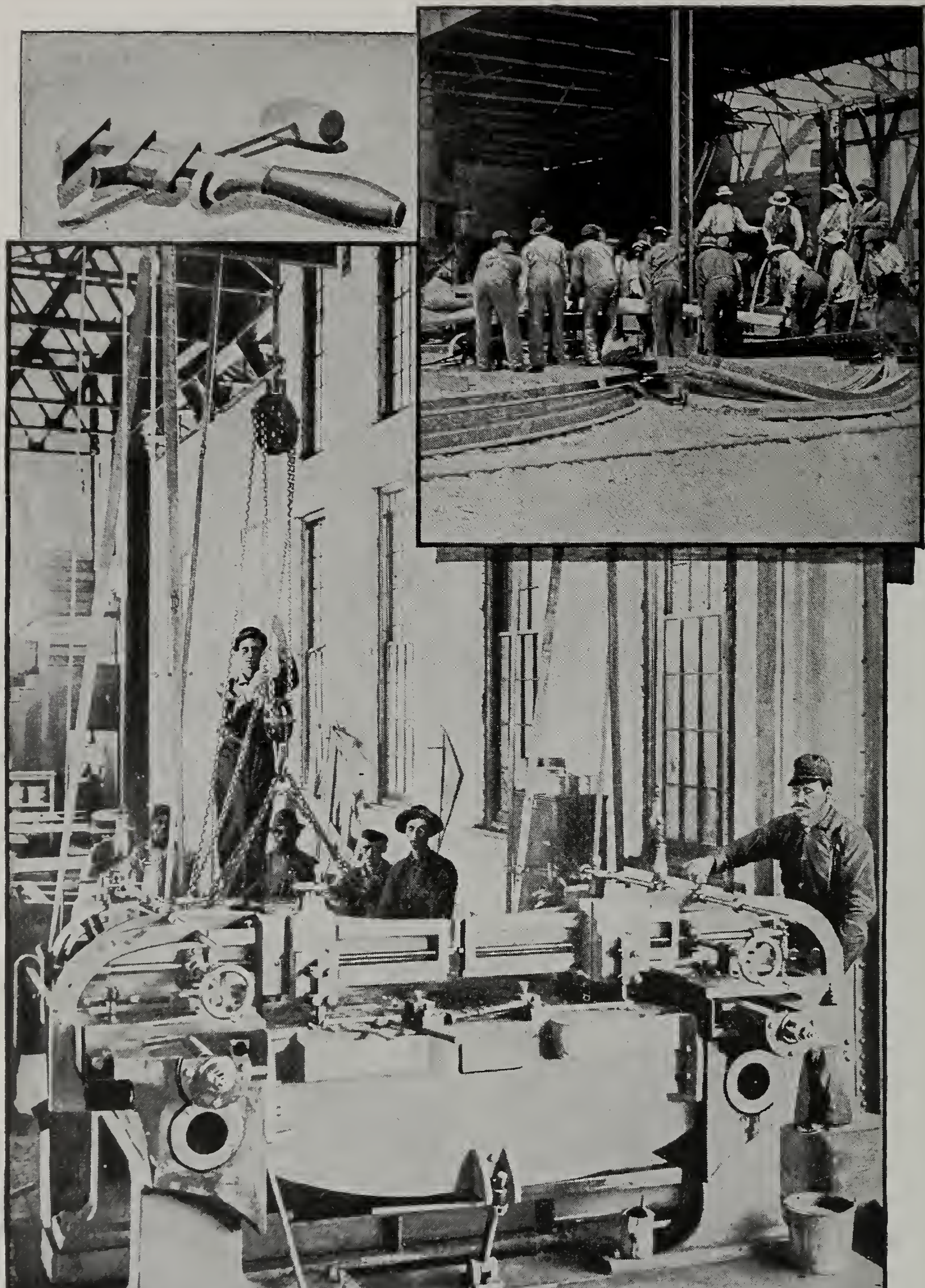


FIG. II. MACHINE FOR SCARPING SHIP-PLATES, MANUFACTURED BY PEDRICK & AYER, PHILADELPHIA, PA.

let out all possible sound, which is the greatest recommendation to any boiler shop if riveting is being conducted to any great amount. The building is large and attractive, being 100 x 300 feet in size, constructed of iron and brick in two bays of 50 feet each. It is fitted with hydraulic flanging machine, 10 ft. 6 in. hydraulic riveter, and traveling cranes of 15 tons and 80 tons capacity.

Figure No. 15 shows a 24-inch slotting machine, built by Bement, Miles & Co., and like their other contributions to this plant, it is eminently satisfactory and equally effective. All material handled is by the aid of traveling cranes and hydraulic apparatus. It is really startling to see the immense plates swing as easily as a glass-blower swings a cylinder, and the flangers and rolls take a plate and work it into shape with as much ease as if it were pasteboard.

Another important matter should be noted, and that is the plan of running each department with an independent engine, together with the additional feature of driving each large machine with a separate engine, so that it is possible, where it is necessary to work overtime, in one department, to do this to any extent independently and without involving any other. Morever, by this plan, the arrangement of special tools can be facilitated, and in case of any breakdown its great advantages are obvious. All the power is derived from one central fireproof house, which contains six boilers aggregating something over 1000 horse-power, and the steam is carried from 400 ft. to 500 ft. in either direction by means of a subway 6′ to 8′ in diameter, which is also used for con-

SOMMERS N. SMITH.

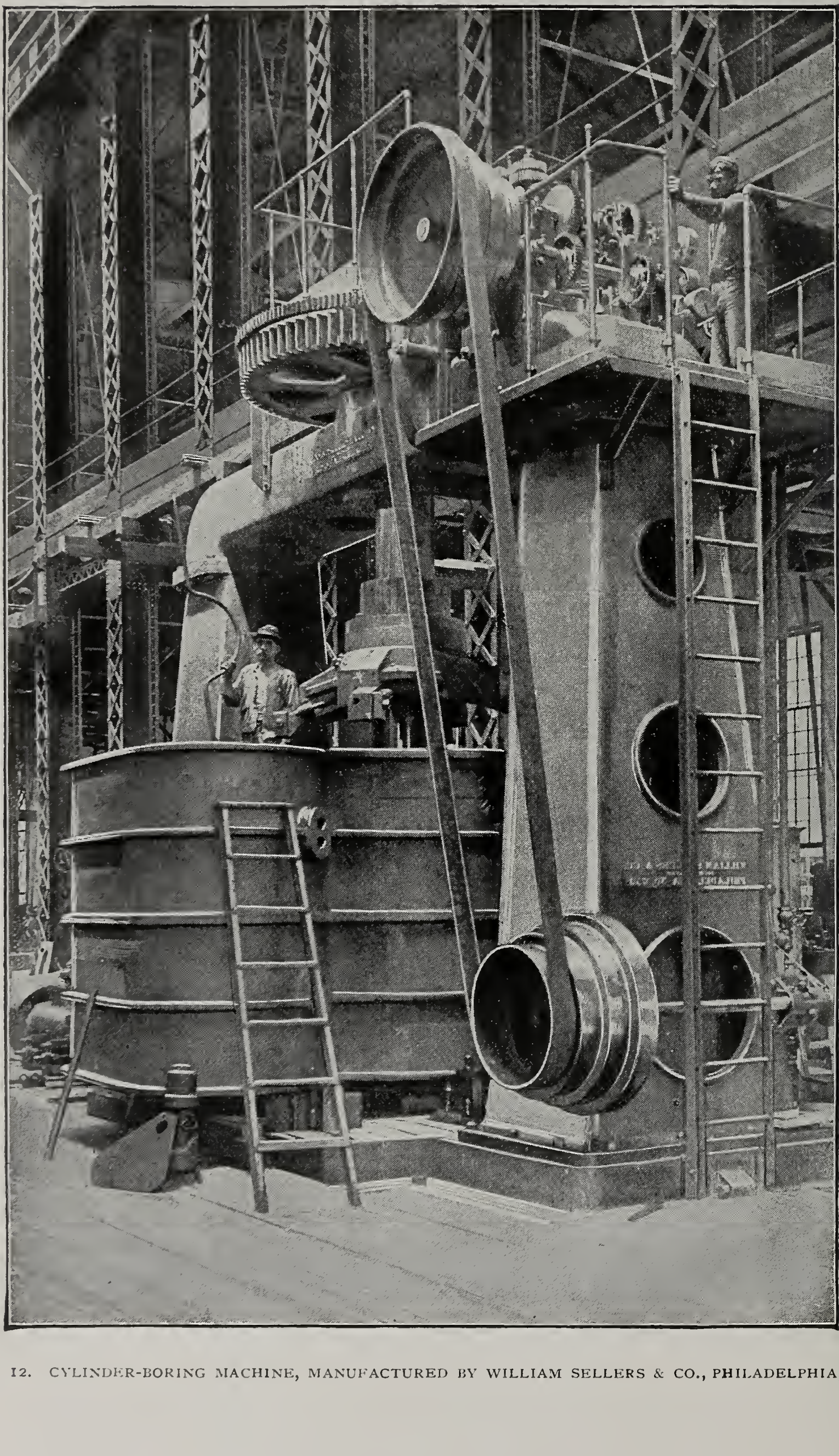


FIG. 12. CYLINDER-BORING MACHINE, MANUFACTURED BY WILLIAM SELLERS & CO., PHILADELPHIA, PA.

ducting heated air to the various shops by means of a large fan; hydraulic mains and electric-light wires are passed through this subway to the several buildings connected therewith. This plan has not only the recommendation of economy, but also the most decided advantage of having the entire apparatus under the immediate control of a single engineer. In case of a fire this cannot be overestimated, and as to fire protection, it may be said the company have a ten-inch main and several eight-inch mains running to the James river, all connected with a powerful steam-pump. There are fire-plugs scattered throughout the yard and many thousand feet of hose ready for immediate use.

It is not only necessary to the success of a great enterprise that machinery should be perfected and suitable buildings constructed, but to render the establishment permanent and give it every chance of success it is quite essential to study the question of suitable and attractive homes for the employees, and in a new country to further provide them with schools for their children, stores for their daily supplies, with churches, and to set in operation social pleasures and relaxations for their hours of rest. Unless this is done, the workmen degenerate into mere machines, they wear out soon, and it is impossible to keep a permanent force, or even to obtain the better classes of workmen. This whole problem has been carefully studied, and, like the mechanical one, has been brought to a successful result.

The Old Dominion Land Company, of which Mr. C. B. Orcutt is the president, and to whom it largely owes its success, has certainly accomplished wonders.

To show what has been done for the inhabitants in regard to their homes, it is only necessary to glance at Fig. 21. This row consists of well-arranged brick buildings, convenient and pleasant, with ample water-supply running from a subterranean stream, while in front of the hotel is a park with a casino, bowling alley, and other pleasant structures.

FIG. 21. A ROW OF WORKINGMEN'S HOMES.

Of course no community is perfect, no matter how well cared for, unless it has a good hotel, and travelers often shun a city whose enterprise lacks a good hostelry. Fig. 16 shows the interior and exterior of the Hotel Warwick, and the writer, who has stayed there on several occasions, does not hesitate to pronounce it a well-kept house, run on liberal principles, having airy, commodious and

FIG. 16. HOTEL WARWICK.

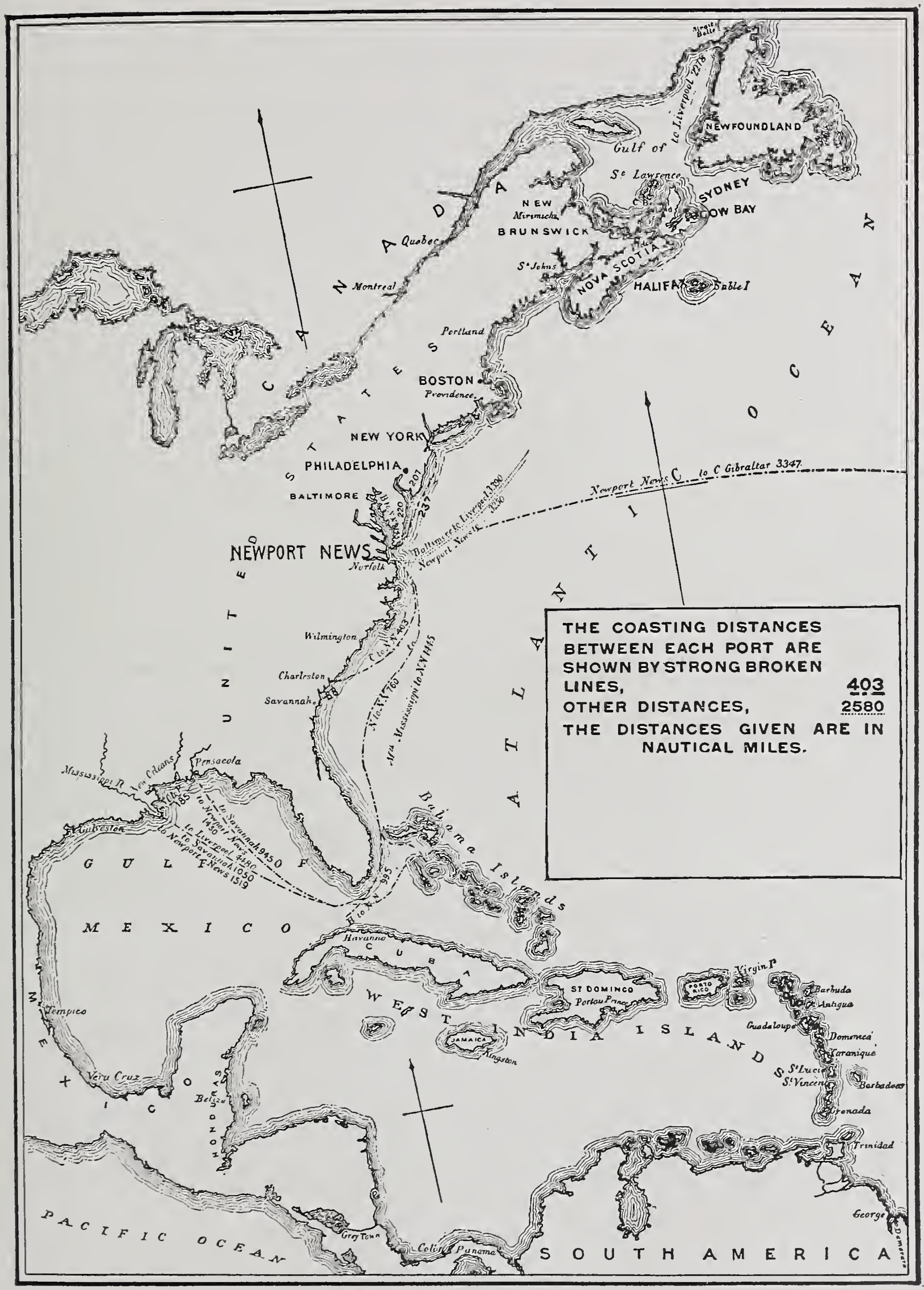
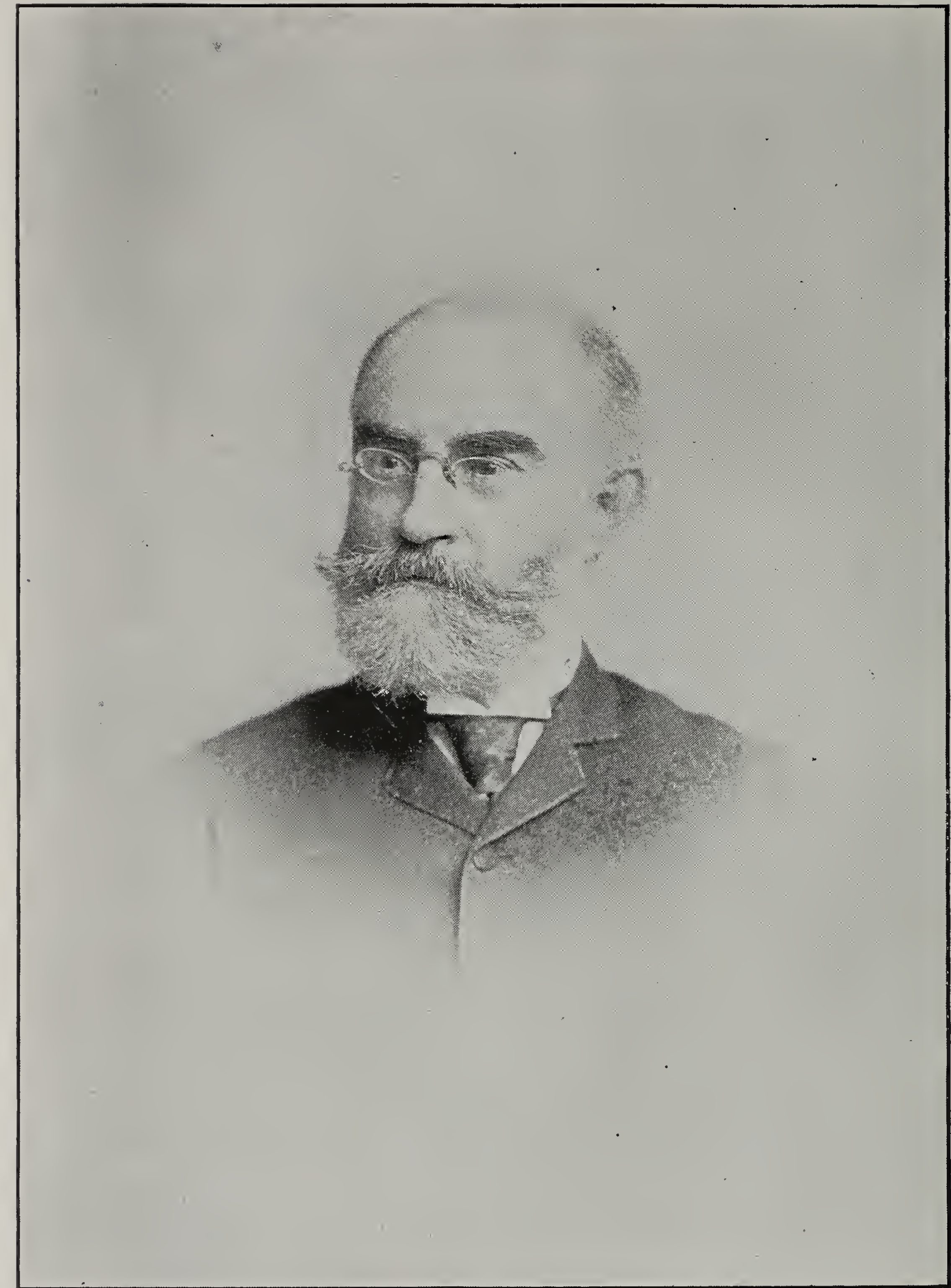


FIG. I. ATLANTIC COAST LINE, SHOWING LOCATION OF NEWPORT NEWS.



scrupulously neat bedrooms, and with a general air of comfort and luxury, which is further evidenced by a good table and all the appointments going to make up an attractive place for gentlemen and their families. Many come here in preference to the more pretentious and less comfortable hotel at Fortress Monroe.

On other pages are printed portraits of Horace See, the consulting engineer for these works, and of Sommers N. Smith, the general superintendent.

Horace See, who is one of the best-known engineers in America, designed the machinery and superintended the construction of many well-known vessels, among which may be mentioned, U.S.N. cruisers *Philadelphia* and *Newark*; dynamite cruiser *Vesuvius*; gunboats *Yorktown*, *Concord*, and *Bennington*; yachts *Atalanta* and *Corsair*; Ss. *El Mar*, *El Monte*, *El Norte*, of the Morgan line; the *Tacoma*, *San Pedro*, and *San Pablo*, of the Central R. R. Co.; the *Caracas*, *Valencia*, *Philadelphia*, and *Venenzuela*, of the Red D. line; *Mariposa* and *Almeda*, of the Sandwich Island line; and the *Monmouth*, of the N. J. C. R. R. Co.

Mr. See was born in Philadelphia, July 16, 1835. After receiving a classical education, he served a regular apprenticeship with J. P. Morris & Co. Upon the completion of his apprenticeship, Mr. See assumed the position of chief draughtsman, and later as superintending engineer, with Messrs. Neafie & Levy, of Philadelphia. Next he was engaged as superintendent of the National Iron Armor & Shipbuilding Co., of Camden, N. J. In 1868, Mr. See was with Mr. Geo. H. Snyder, of Pottsville, Pa., where as engineer and assistant superintendent, he designed and constructed the machinery for the Lehigh and Susquehanna planes at Wilkesbarre, and the hoisting and pumping machinery for many of the prominent anthracite coal mines. When Messrs. Cramp & Sons began building iron vessels, in 1871, they secured Mr. See as chief draughtsman.

Mr. See is an ex-president of the American Society of Mechanical Engineers, member of the Franklin Institute, associate member of the U. S. Naval Institute, fellow of the American Society for the Advancement of Science, and also a member of the Engineers' Club of New York and the Engineers' Club of Philadelphia. He resigned his position with Messrs. Cramp in August, 1889, since which time he has been located in New York as Consulting and Superintending Engineer.

Pictures and words convey impressions, but as a closing statement it may be well to quote facts as shown in the following extract from the *Manufacturers' Record*, for April, 1891, with the remark that a great advance has been made in Newport News since that date:

"The exports from Newport News for February, 1891, were $2,038,376, which was only $218,000 less than the exports from Philadelphia for the same month, and $300,000 greater than from Richmond, and only about $300,000 less than from Charleston, S. C. Newport News thus comes to the front at once in rank with such established cities as Charleston, Norfolk, and Philadelphia in its export trade. Its exports for the eight months ended February 28, 1891, were $6,774,000, against $3,664,000 for the corresponding months of 1890. This is by far the largest percentage of gain shown by any port in the United States. During the same time the exports of Baltimore have decreased $4,000,000, showing how heavily Newport News is cutting into the foreign trade of Baltimore. For the eight months ended February 28, 1890, the foreign exports of Newport News were less than one-sixth of the exports from Philadelphia. For the corresponding eight months ended February 28, 1891, the exports from Newport News were one-third as large as Philadelphia's. The value of breadstuffs exported from Philadelphia in March, 1891, as given by the chief of the Bureau of Statistics of the United States Treasury, was $717,862, while the value of those shipped from Newport News was $766,098. It may be added that the cash value of exports for the year ended September 30, 1891, was $12,015,748."

DISTRIBUTION MAINS AND FIRE SERVICE.

By J. T. Fanning, Mem. Am. Water Works Asso.

IN a paper on this subject read before the American Water Works Association the writer said that inefficiency of the water supply is the statement that comes to us again and again as a stereotyped sentence in current reports of large fires. These reports emphasize the fact that it is always important that each public water-supply system shall be a good and efficient fire-controlling system.

In a majority of the towns and cities that have built water supplies under municipal ownership, it is probable that the desire for fire protection was the strongest incentive to the general public and the chief influence that carried the vote for the issue of bonds to pay for water works.

Fire may be a grand spectacle to one who has no personal interest other than to enjoy its grandeur; it may interest one who studies the plan of contest to control it; but it is a waste for which there is no recompense, a discouragement, as of ill fate, to the loser, and awful in the extreme when human lives are engulfed in the ruin.

All the great cities of the civilized world transmit in their histories lurid stories of great devastations, and the sum of fire losses in great fires of American cities alone seems fabulous.

A committee of the National Board of Fire Underwriters estimates the average annual waste of values by fire during the last decade as exceeding $100,000,000, and claims that the annual loss is increasing.

Boston has had five great historic fires, St. Louis three, New York two, Philadelphia two, and Pittsburgh, Albany, San Francisco, Washington, Portland, Chicago, Lynn, Spokane and Seattle successively, and a host of small cities, have seen the fire fiend cut his broad swath through their midst. Are failures, so often recurring, due in any large degree to a lack of knowledge of the principles and proportions of a good fire-hydrant service?

New fire systems are being constantly planned in the new cities, and old systems are being constantly extended, so that it may be profitable to consider just how far the successive steps in planning a new or extending an old system are governed by simple rules requiring only easy mathematical demonstrations or computations.

Force of Hose-Jets.—The making of a good fire-hydrant service is the form in which the problem comes to the young and enterprising city, and the maintenance the form in which the problem comes to the older city. Towns or cities of less than 10,000 inhabitants have comparatively few three-story or other buildings requiring fire protection that reach 40 feet in height. Cities of 10,000 to 25,000 inhabitants have comparatively few four-story or other buildings that exceed 50 to 60 feet in height, and these heights cover their municipal, court, and hospital buildings. The large cities have buildings 80, 100, and 125 or more feet in height. As a general rule, streams that have force to reach a vertical height of 80 feet from the ground answer well nearly all requirements of small cities and the suburbs of large cities, and also the business sections of cities where buildings do not exceed 60 to 70 feet, say 5 to 6 stories in height. The high office buildings of large cities require a special adaptation of the fire service.

Our present interest does not extend to such hose-jets as were given at the Centennial test in 1876, when 1⅞-inch streams were thrown 199 feet vertically, or to such a stream as was shown at the Syracuse convention of firemen in 1885, reaching 316 feet horizontally from a 1⅝-inch nozzle.

Those were maximum tests, and tournament streams rather than for practical fire service.

Volumes of Hose-Jets.—A thorough knowledge of the volume of water and rate of discharge of the fire streams to be used is a first essential in the preparation of a plan of a fire system.

To illustrate the value of this, we will compute and tabulate a series of serviceable streams having force to reach to given heights,—70 to 100 feet vertically, and from nozzles 1, 1⅛, 1¼, and 1⅜ inches diameters. The units, gallons, or million gallons per 24 hours are of such frequent and familiar use in water-supply statements and mental comparisons that the computations are also stated in these terms, and may consequently be easily compared with capacities of distribution pipes, standpipe tanks, and pumping machinery.

Table No. 1 covers the ordinary range of forces of jets and volumes of discharges, and will indicate what provision per jet must be contemplated in the flow of the distribution pipes.

We observe in the table, for instance, that if we use a 1⅛-inch nozzle a stream of 70 feet vertical force discharges at a rate of ⅜ million gallons; a stream of 80 feet force discharges at the rate of 4-10 million gallons; a stream of 90 feet force discharges at the rate of 5-10 million gallons; and a stream of 100 feet force discharges at the rate of ⅔ million gallons; approximately, also, if we use 100-feet streams the 1¼-inch nozzle discharges at the rate of ⅔ million gallons, and the 1⅜-inch nozzle discharges at the rate of ¾ million gallons, approximately.

The above jets may be from hose connected directly to the fire hydrants, or equivalent jets from steam fire engines which take their water from the hydrants. The volume of the jet will be the same for the same nozzle and height of stream.

Rated capacities of steam fire engines, which are perhaps ⅓ greater than the ordinary rate of work at fires, are substantially as follows:

3d size,	550 gallons per minute, or rate			792,059 gallons per 24 hours.		
2d "	700	"	"	1,008,750	"	"
1st "	900	"	"	1,296,096	"	"
1 (extra)	1100	"	"	1,584,118	"	"

In preparation of the plan of distribution there must be an estimate, with wise forethought, of the number of these strong streams, or the number of those steamers that will work at their utmost speed and draft at the same time.

TABLE No. 1.

DATA OF PRACTICAL FIRE STREAMS.

Vertical Height of Stream.	Diameter of Nozzle.	Pressure at the Play-Pipes.	Horizontal Projections of Streams.	Gallons per Minute.	Rate in Gallons per 24 Hours.
Feet.	Inches.	Pounds.	Feet.	Gallons.	Gallons.
70	1	46.5	59.5	203	292,298
70	1⅛	44.5	61.3	249	358,520
70	1¼	43.0	66.0	306	440,619
70	1⅜	41.5	77.0	368	530,149
80	1	59.0	67.0	230	331,200
80	1⅛	55.5	69.5	281	404,700
80	1¼	53.5	72.4	343	493,900
80	1⅜	51.5	74.4	410	590,400
90	1	79.0	76.6	267	384,500
90	1⅛	72.0	78.5	324	466,600
90	1¼	68.5	81 0	388	558,800
90	1⅜	65.5	82.6	468	674,000
100	1	125.	88.0	311	447,900
100	1⅛	103.	89.0	376	541,500
100	1¼	93.	92.0	460	662,500
100	1⅜	88.	92.0	540	777,700

Friction Losses in Hose.—In the above table of data of practical hose-streams the volumes of water discharged per jet—200 to 550 gallons per minute—were for stated pressures at the play-pipe.

In providing for this pressure due allowance is to be made for friction losses in each hose according to the streams of greatest discharge which are to be used.

The loss of pressure or its equivalent loss of head (h) in the hose may be found by the formula :

$$h=v^2(4m)\frac{1}{2gd}$$

In this formula, as ordinarily used, for friction per 100 feet of 2½-inch hose there are constants, viz.: 2½-inch diameter of hose, d=.20832 feet and sec.=.0434 square feet; length of hose, l=100 feet, and 2g=64.4; and the variables, v=velocity in feet per second, h=loss of head in feet per 100 feet of hose, m=a coefficient previously found by a series of experiments.

The velocity, *v*, is found from the given discharges of the jets through the given diameter of hose.

A series of these friction losses for given discharges in jets, when tabulated, is a ready aid in arriving at the pressure that must be provided at any given hydrant. In Table No. 2 are given friction losses in 100-feet lengths of rubber-lined, smooth 2½-inch hose.

These frictions are for given volumes of flow in the hose, and the velocities respectively due to those volumes, and are independent of size of nozzle. The changes in nozzle do not affect the friction in the hose if there is no change in velocity of flow; but a larger nozzle with equal pressure at the nozzle augments the discharge and velocity of flow, and thus materially increases the friction loss in the hose.

To illustrate further the frictional effect of change of nozzles, take from Table No. 1 the same streams and tabulate in No. 3 their friction losses in each 100 feet of a smooth, rubber-lined 2½-inch hose.

Loss of pressure, *p*, and head, *h*, in rubber-lined, smooth 2½-inch hose may be found approximately by the following formulas :

$$p=\frac{lq^2}{4150\,d^5} \quad \text{and} \quad h=\frac{lq^2}{1801\,d^5}$$

in which p=pressure lost by friction, in pounds per square inch; l=length of hose in feet; q=gallons of water discharged per minute; d=diameter of the hose in inches—2½-inch; h=friction head in feet.

The coefficient would be decreased for rougher hose.

TABLE No. 2.

HEAD AND PRESSURE LOSSES BY FRICTION IN HOSE.

Discharge of Water per Minute.	Velocity of Flow per Second.	Coefficient in Formula $h=v^2(.4m)\frac{1}{2gd}$	Head Lost in 100 Feet of 2½-inch Hose.	Pressure Lost in 100 Feet of 2½-inch Hose.	* Value of *n* in $v=n\,(r\,s)^{1/2}$ $n\left(\frac{2g}{n}\right)^{1/2}$	Rate in Gallons per 24 Hours.
Gallons.	Feet.	m.	Feet.	Pounds.	n.	Gallons.
200	13.072	.00450	22.89	9.93	119.6	288,000
250	16.388	.00446	35.55	15.43	120.0	360,000
300	18.858	.00442	46.80	20.31	120.9	432,000
347	21.677	.00439	61.53	26.70	121.1	499,680
350	22.873	.00439	68.48	29.73	121.2	504,000
400	26.144	.00436	88.83	38.55	121.5	576,000
450	29.408	.00434	111.80	48.52	121.8	648,000
500	32.675	.00432	137.50	59.67	122.1	720,000
520	33.982	.00431	148.40	64.40	122.12	748,800

* Values of *n* are deduced from the elaborate experiments on fire streams by John R. Freeman, C.E., given in Transactions of American Society of Civil Engineers, No. 426, November, 1889.

Hose-Jets Compared.—The problems introduced by changes of nozzle are so numerous that it will be a convenience to assume a standard stream for this discussion, and so compare other streams with this standard that they may be easily kept in mind.

If we assume first a standard height of 80 feet, then discharges may be from different diameters of nozzle approximately :

1	inch stream,	230	gallons per	minute,	rate of	.33	million	gallons.
1⅛	" "	281	"	"	"	.40	"	"
1⅛	" "	343	"	"	"	.49	"	"
1⅛	" "	410	"	"	"	.60	"	"

The 1⅛-inch stream, with power to reach a height of 80 feet, is a good standard for a small city or the suburbs of a large city, and this discharges water at a rate of, approximately, 4-10 million gallons per 24 hours, a quantity easily remembered or multiplied for comparisons.

The loss of pressure and head for this standard stream is, in each 100 feet of 2½-inch hose, approximately 20 pounds, or 45 feet net ; or say, including friction in the hydrant, ½ (.5) foot loss of head for each foot of hose, another quantity easily remembered or multiplied.

If we change the nozzles to 1¼- or 1¾-inch diameters, then for the same 80-foot height of stream we increase the friction losses on the hose to, approximately, ⅔ foot and 1 foot head respectively for each foot-length of hose.

These computations show the very great difficulty of maintaining a high stream through the large nozzles, unless the hose is very short, especially for a gravity or direct-pressure system.

Our standard single 1⅛-inch stream requires, approximately, 56 pounds pressure, or equivalent 129 feet head at the play-pipe and 45 to 50 feet head for each 100-feet length of smooth 2½-inch hose, so that for 100, 200, and 300 feet of hose we must have available heads at the hydrant or fire engine of 106, 156, and 206 feet respectively. If we substitute 1¼-inch nozzles for same height of stream, we must have available heads at the hydrants or engine 185, 255, and 325 feet respectively, or we must increase the diameter of a portion at least of the long hose, and save friction loss of head.

Large streams from portable water

TABLE NO. 3.

FRICTION LOSSES FOR GIVEN STREAMS.

Stream.	Stream.	Pressure at the Play-Pipe.	Friction per 100 Feet of Hose.	Friction per 100 Feet of Hose.
Inches in Diameter.	Height in Feet.	Pounds per Square Inch.	Pounds per Square Inch.	Net Head.
1	70	46.5	10.75	24.77
1	80	59.0	13.50	31.10
1	90	79.0	17.70	40.78
1	100	130.0	22.50	54.14
1⅛	70	44.5	15.50	35.71
1⅛	80	55.5	19.40	44.70
1⅛	90	72.0	25.40	58.52
1⅛	100	103.0	33.80	77.88
1¼	70	43.0	22.75	52.42
1¼	80	53.5	28.40	65.43
1¼	90	68.5	35.90	82.71
1¼	100	93.0	57.75	86.98
1⅜	70	41.5	32.50	74.88
1⅜	80	51.5	40.00	92.16
1⅜	90	65.5	51.40	118.43
1⅜	100	88.0	72.00	165.89

towers are most serviceable when the streams are supplied by one or more steam fire engines capable of maintaining a good pressure at the elevated nozzle. The discharge for given pressures at the nozzles are substantially as follows :

TABLE NO. 4.

VOLUMES OF PORTABLE TOWER-STREAMS.

Pressure at Nozzle.	Diameter of Nozzle.	Gallons per Minute.	Gallons per 24 Hours.
Pounds.	Inches.	Gallons.	Gallons.
40	1½	433	623,820
40	1¾	663	810,847
40	2	735	1,058,444
40	2½	1158	1,696,970
50	1½	463	666,060
50	1¾	630	906,553
50	2	822	1,184,051
50	2½	1285	1,850,234
60	1½	507	729,544
60	1¾	674	970,487
60	2	901	1,297,032
60	2½	1407	2,026,854

Number of Hose-Jets Required.—Thus far the volumes and frictions of one good fire stream only have been considered. Now certain numbers of these 4-10 million gallon streams must be assumed for computations of friction losses in the main, and distribution pipes of water-supply systems of different magnitudes.

We will assume the judicious provision of 80-foot fire streams for the ordinary fire service of cities having the populations named to be substantially as follows :

Population, 4000 to 10,000 ;	streams, 7 to 10 ;	rates, 3.84 to 5.48	million gallons.
" 10,000 to 50,000 ;	" 10 to 14 ;	" 5.48 to 7.68	" "
" 50,000 to 100,000 ;	" 14 to 18 ;	" 7.68 to 9.87	" "
" 100,000 to 150,000 ;	" 18 to 23 ;	" 9.87 to 12.62	" "

Combined Fire Service and Domestic Draft of Water.—In American cities populations of 4000 use for ordinary domestic purposes about .2 million gallons daily ; populations of 10,000 use .6 million gallons ; populations of 50,000 use 4.4 million gallons ; populations of 100,000 use 10. million gallons, etc., the rate per capita increasing with the total population, and being here stated as mean daily consumption for each year.

We have for these four assumed cases combined mean rates of 4.04, 6.08, 12.08, and 19.87 million gallons respectively per 24 hours as the flow in the supply mains when a fire is in progress at midday.

The domestic draft of water will be greater in volume in certain hours of the day and at certain seasons of the year.

The drafts for the fire service in the principal mains of the village system will be ten times the draft for domestic use, and may be always in excess until the city has a population of 80,000 to 100,000.

The excess of draft for fire service continues in the suburbs and sub-districts of cities, and must be provided for in the sub-mains and distribution pipes,—not less than 7 standard streams in the suburbs, and increasing to 10 and 12 streams as the manufacturing or commercial centers are approached, and the full force of 18, 20, or 30 streams in the centers of industries, trade, and shipping, according to their values and importance.

Friction in Distribution Pipes.—From lessons of experience a maximum advisable velocity (v) of flow, or, as better termed for our present purpose, a maximum advisable loss of head (h) by friction in pipes of different diameters, is assumed to be as follows, using as before the formula $h = \frac{41 m v^2}{2gd}$ and d being taken in feet.

It may be remarked that these maximum losses of head can rarely be allowed when computing for the portions of gravity or direct-pressure systems distant from the origin of the head or pressure when the hose for fire streams is to be attached directly to fire hydrants without the intervention of steam fire engines. The alternative, then, is to take a pipe of larger diameter.

When steam fire engines are used, an allowance must be made in computing friction for maintaining at least 100 feet

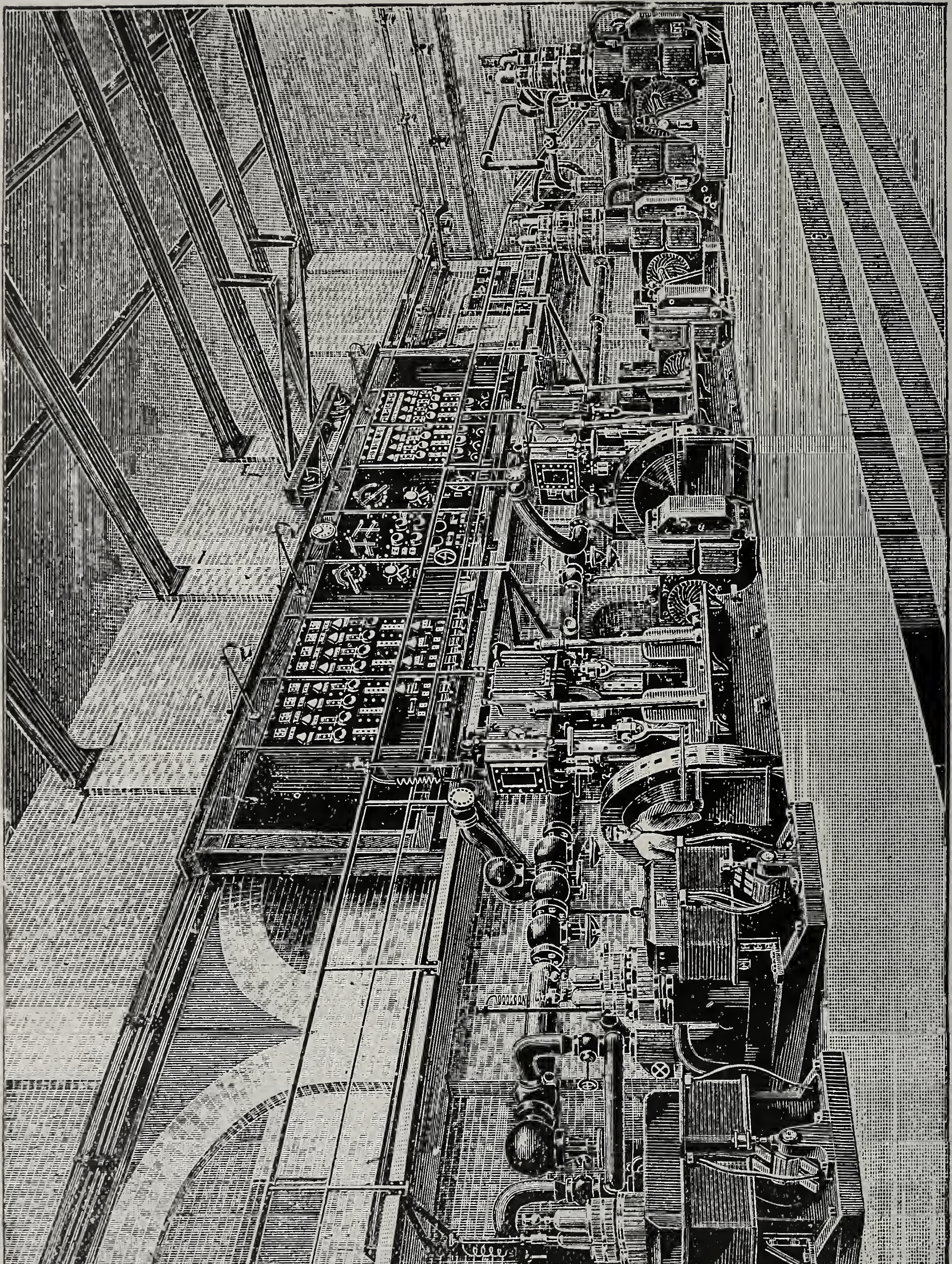
of head in the dense residence sections to provide the necessary domestic pressure in the chamber bath-rooms and sanitary tanks.

Proportioning Distribution Pipes.—In computing for the fire service, we find it advisable to begin with the hose-stream in the air, and work backward through nozzle, hose, hydrant, and branch pipe into the distribution. So in computing for the pipe system we should begin with the distribution in each of the small sub-divisions, and compute the volume of the fire service there according to the surroundings, and then the local, domestic, commercial, industrial, mechanical, and ornamental drafts of water, allowing for growth of the local sections, then summing the volumes of these local sections into the sub-mains, and then all together into the principal mains, and through this course we reach the maximum rate of outflow from the pumping machinery of the direct-pressure system, or from the reservoir or tank standpipes.

TABLE NO. 5.

Diameter.	Velocity of Flow.	Coefficient.	Friction in 1000 Feet of Length of Pipe.	Friction per Mile.	Rate of Flow per Minute.	Rate of Flow per 24 Hours.
Inches.	Feet per Second.	m.	Head in Feet.	Head in Feet.	Gallons.	Gallons.
4	3.10	.00647	11.59	61.195	121,849	174,859
6	3.9	.00608	11.49	60.667	343.675	494,892
8	4.5	.00575	10.83	57.182	704 84	1,014,970
10	5	.00556	10.36	54.701	1,223.88	1,762,384
12	5.5	.00536	10.07	53.169	1,938.66	2,791,701
14	5.8	.00520	9.33	48.246	2,782.65	4,007,016
16	6.	.00507	9.069	47.884	3,761.84	5,417,052
18	6.25	.00494	7.99	41.187	4,956.643	7,127,266
20	6.5	.00476	7.5	39.6	6,362.41	9,161,875
24	6.75	.00454	6.42	33.918	9,528.37	13,706,460
27	6.90	.00440	5.78	30.534	12,312.56	17,689,951
30	7.	.00425	5.17	27.318	15,422.114	22,207,845

(To be continued.)



A ROW OF DIRECT-COUPLED ENGINES AND DYNAMOS AT ECCLESTON PLACE STATION OF WESTMINSTER ELECTRIC SUPPLY CORPORATION, LONDON.

DIRECT-CONNECTED ENGINES.—II.

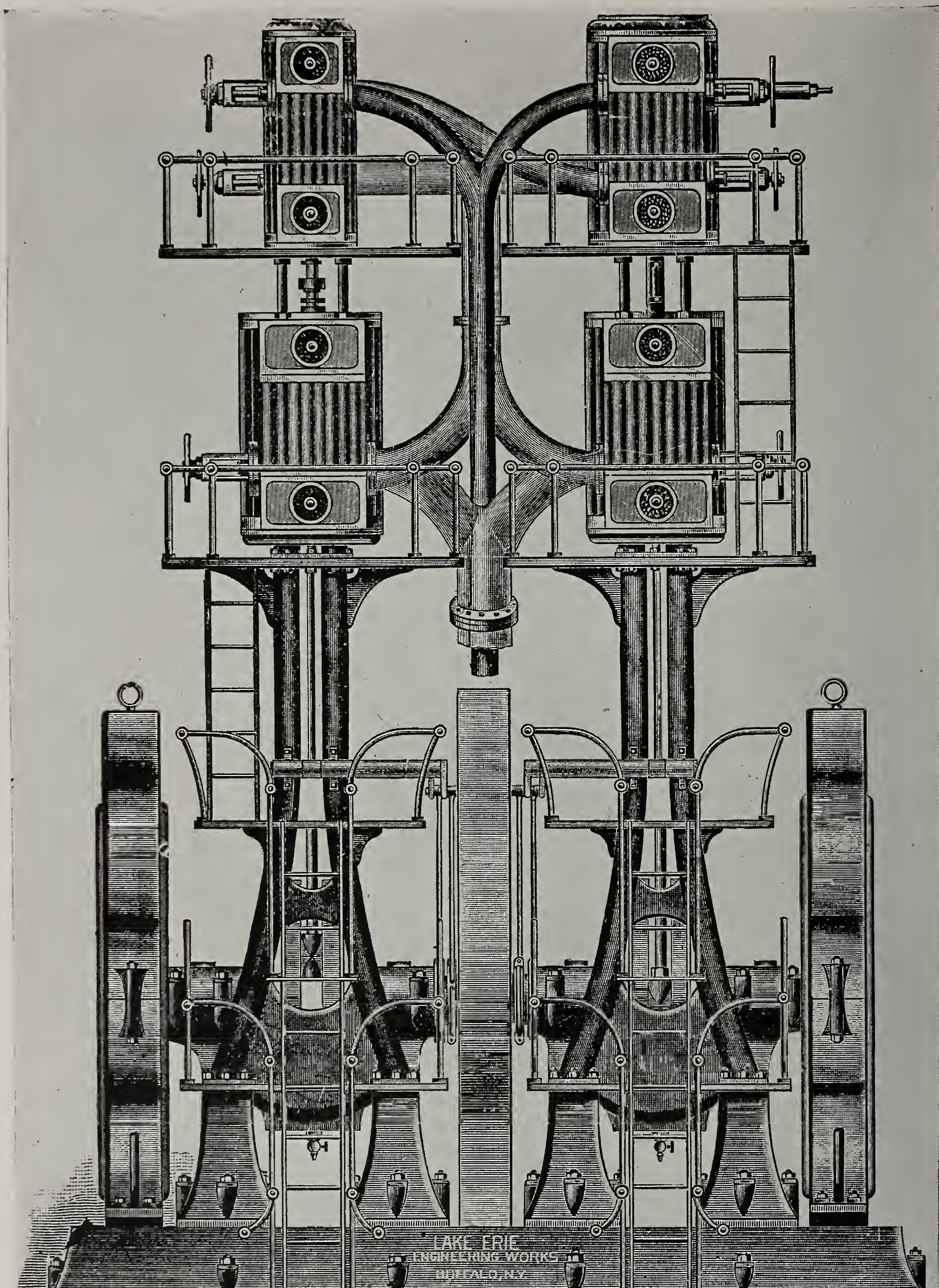
By Charles H. Werner.

THE demand for a special class of engines for use in the electrical industries of Great Britain has caused a number of firms to bend their attention to the question, and although up to the present the great Lancashire firms who build with such success the large slow-speed engines for cotton machinery have almost entirely disregarded the electric-light industry, yet another class of engineers, those who have gained special experience in steam-launch and torpedo-boat work, finding the problems usually put in installation work somewhat similar to those they are used to, have taken up this new branch of engine-building. Among these, the firm of Messrs. G. E. Belliss & Co., of Birmingham, have taken a leading place. They make central-valve dynamo engines, which are made both compound and double cylinder, and have replaced single-acting, closed-in engines on board ship with much success. Messrs. Belliss also build an enclosed double-acting, high-speed engine. The method of lubrication adopted by them on these engines allows the lubricant to be delivered to all the bearings under pressure, either direct from a force pump or from a tank placed at a suitable elevation, and through oil channels arranged in the interior of the various journals. A casing encloses the working parts, access being afforded by doors. In this way they are kept free from dirt and dust, and by a simple arrangement the oil that has passed through the bearings is available for redistribution, so that there is no waste of lubricant.

The use of gas engines for central stations has been carefully considered for some time, but little has thus far been done in that direction. Messrs. Schleicher, Schumm & Co., of Philadelphia, builders of the "Otto" engine, recommend generally the use of a countershaft with a fly-wheel for engines of 20 horse-power and upwards. This firm have lately brought out a special 36 horse-power gas engine for driving a slow-speed dynamo coupled direct. It has two cylinders, working on the same crankshaft, so as to give an impulse every revolution. The dynamo, shown with the engine in the illustration, is of the ordinary form, and gives 100 volts and over 200 amperes. With producer gas as made in England this engine consumes about 1½ pounds of coal per indicated horse-power per hour. It has been said that gas engines cannot be made to run steadily enough for direct driving; this engine, however, is said to run at a sensibly uniform speed.

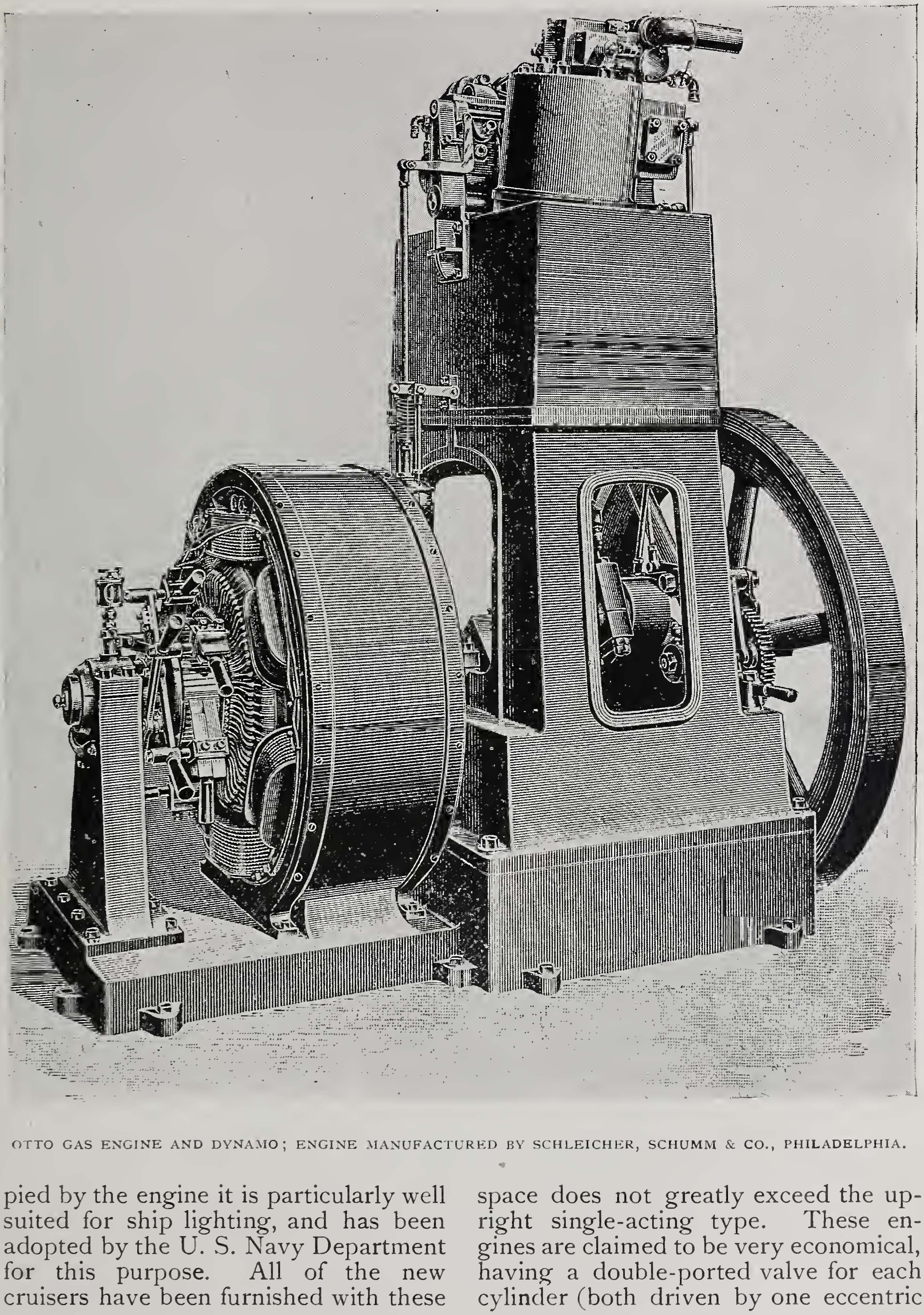
The Lake Erie Engineering Works, of Buffalo, have recently designed some multi-cylinder engines for direct connection to multipolar generators. The rotative speed chosen is somewhat above the limitations imposed by the releasing valve gear of other engines, but is not what is called high speed. The pressures per square inch on the bearings and the rubbing velocities of the journals form the starting point in establishing the rotative speed of these engines, the rate of rotation in the different sizes varying inversely proportional to the diameters of their shafts. The piston speed is universally 650 feet per minute. These engines are built, arranged for direct connection, in sizes from 50 to 5000 horse-power units, and of either compound or triple-expansion type.

Anticipating that some time there would be a demand for an engine to meet the requirements of the electric systems calling for a faster speed than their standard engine could furnish without having a very large driving wheel, the Armington & Sims Company designed a double, double-acting, horizontal engine. This engine, thoroughly tested, proved quite satisfactory,



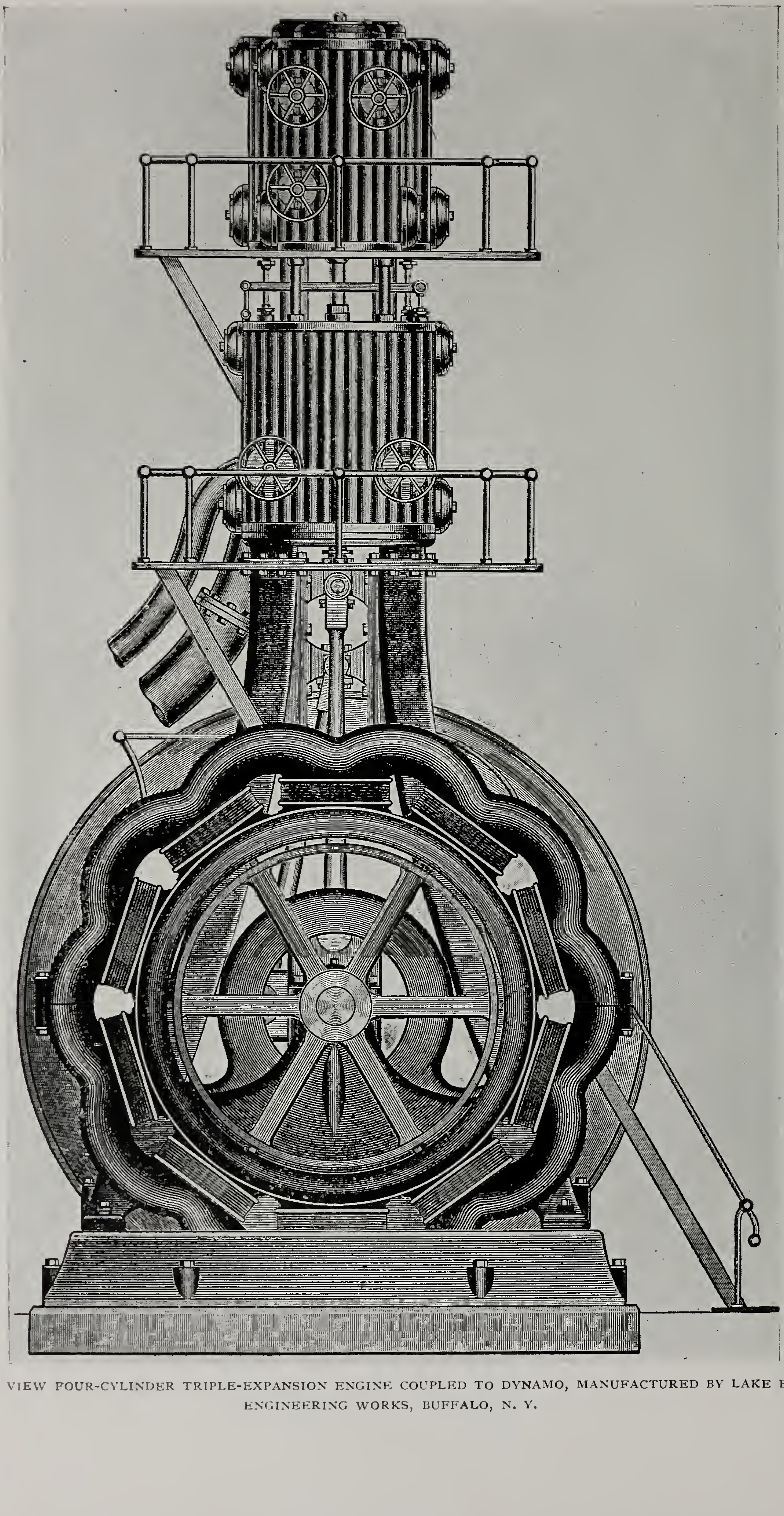
COMPOUND ENGINE AND DYNAMO, MANUFACTURED BY LAKE ERIE ENGINEERING WORKS, BUFFALO, N. Y.

and is now in use at the new works of the Pond Machine Tool Company, Plainfield, N. J., driving the Westinghouse alternating system of electric lighting. From the small space occu-



OTTO GAS ENGINE AND DYNAMO; ENGINE MANUFACTURED BY SCHLEICHER, SCHUMM & CO., PHILADELPHIA.

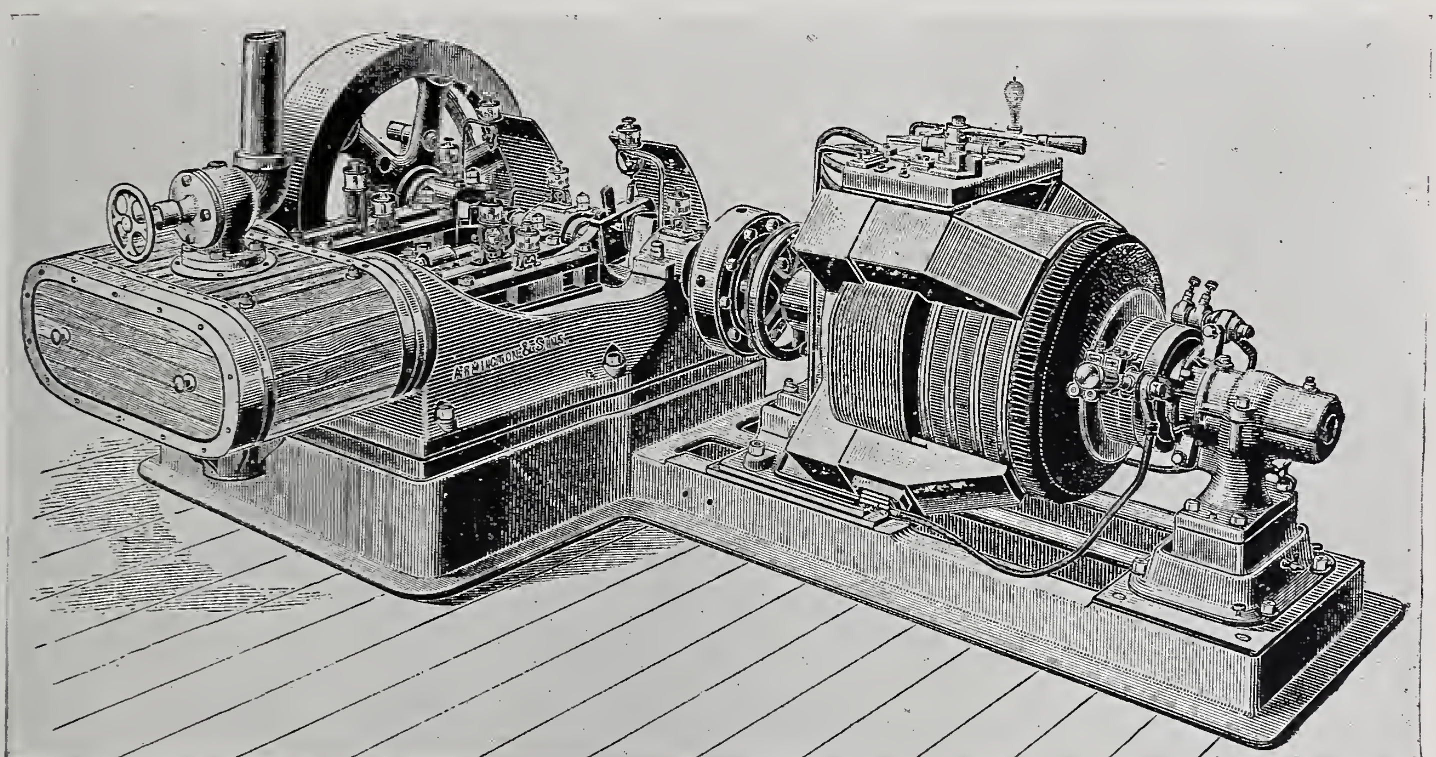
pied by the engine it is particularly well suited for ship lighting, and has been adopted by the U. S. Navy Department for this purpose. All of the new cruisers have been furnished with these engines, either horizontal or vertical. Being double-acting, it requires but one-half the piston area for the same power, and although the connecting rods are all made 6 to 1, yet the floor space does not greatly exceed the upright single-acting type. These engines are claimed to be very economical, having a double-ported valve for each cylinder (both driven by one eccentric



SIDE VIEW FOUR-CYLINDER TRIPLE-EXPANSION ENGINE COUPLED TO DYNAMO, MANUFACTURED BY LAKE ERIE ENGINEERING WORKS, BUFFALO, N. Y.

and cut-off regulator), and the waste room is very small, with quick steam admission. The same cut-off regulator is used on this direct-connected engine as that which the company puts on its standard type of engine.

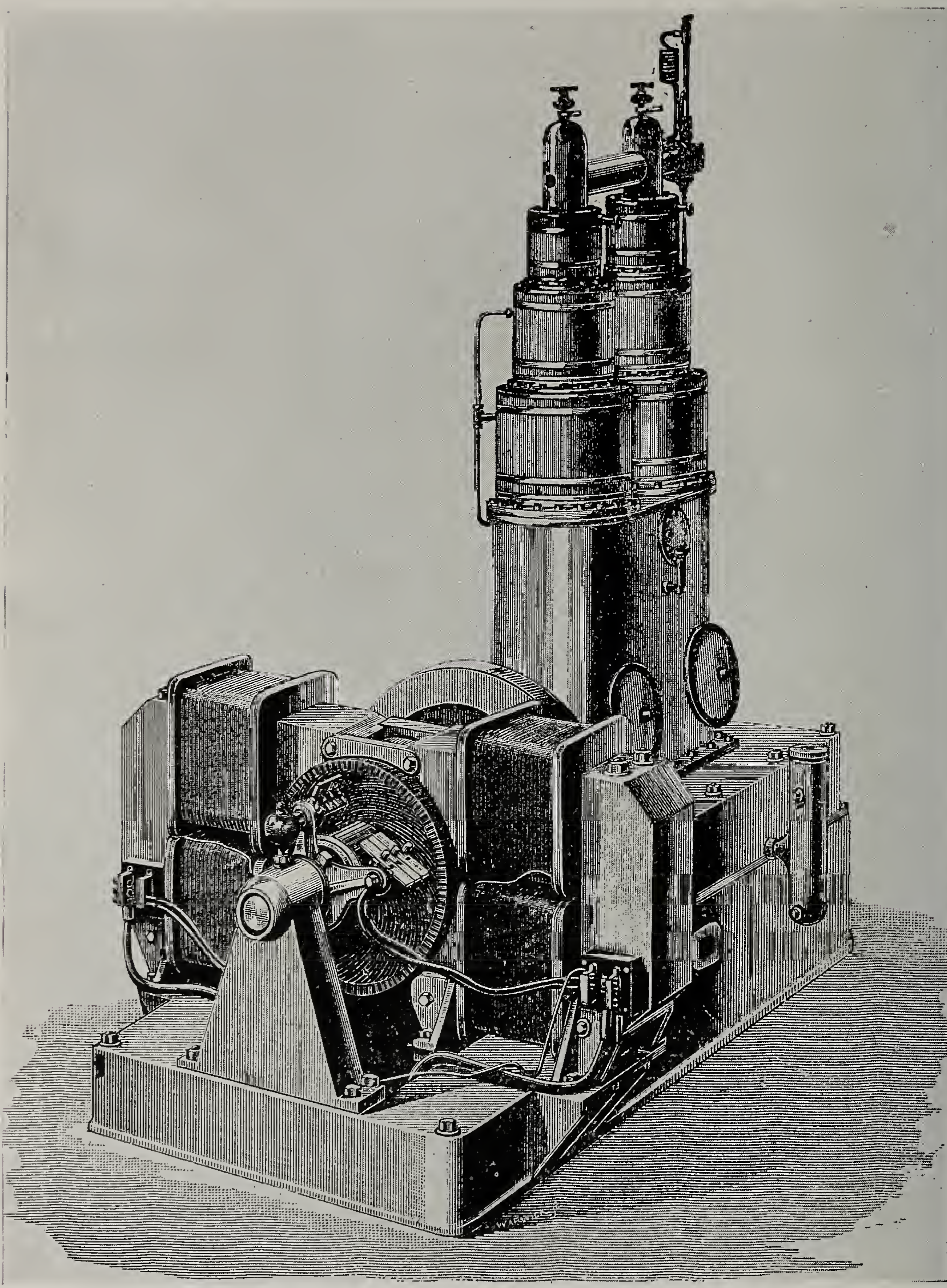
To show the arrangement of an English supply station having direct-connected engines, there is presented on another page a view, taken from a London publication, of the interior of the Eccleston Place station of the Westminster Electric Supply Corporation. It is the intention of this company to make this the center of the system, and a large building has been erected, in which there and the other two a capacity of 500 amperes at 240 volts. In the illustrations these machines are coupled with Willans triple-expansion engines and compound "Windsor" type engines. The combined efficiency of a Willans engine with these dynamos is very high, and 84 per cent. is spoken of as being reached. The engines, by Messrs. Willans, which are coupled to the Crompton dynamos, are of the two 2-crank triple-expansion type. The high-pressure cylinder measures 10 inches diameter, the intermediate 14 inches diameter, and the low-pressure is 20 inches diameter, with a 9-inch stroke.



SPECIAL DOUBLE ARMINGTON & SIMS ENGINE AND EDISON DYNAMO, AS FURNISHED U. S. NAVY DEPARTMENT.

is ample room for the general offices of the company, engineers' rooms, and stores. A remarkable fact in connection with this and the other stations of the company is that each section of the work has, in almost every case, been carried out by a separate contractor. The designs and specifications were, in the first instance, prepared in the company's offices, and afterwards boilers, engines, dynamos, pipes, etc., were each ordered direct from their respective makers. The main supply of current is obtained from a set of four 4-pole Crompton dynamos ; two have a capacity of 300 amperes at 225 volts,

Each engine will indicate up to 200 horse-power when running at a speed of 355 revolutions. In addition there are two 2-crank Willans compound engines, coupled to the Siemens dynamos. The measurement of the high-pressure cylinder is 10 inches and the low-pressure 14 inches. The stroke is 6 inches. The remaining two large dynamos are coupled to vertical compound engines, made by Davey, Paxman & Co., of Colchester, England, and styled by them the "Windsor." This engine, the illustration of which is taken from the *Electrical Review*, is one which for an open machine occupies a small space in proportion to its



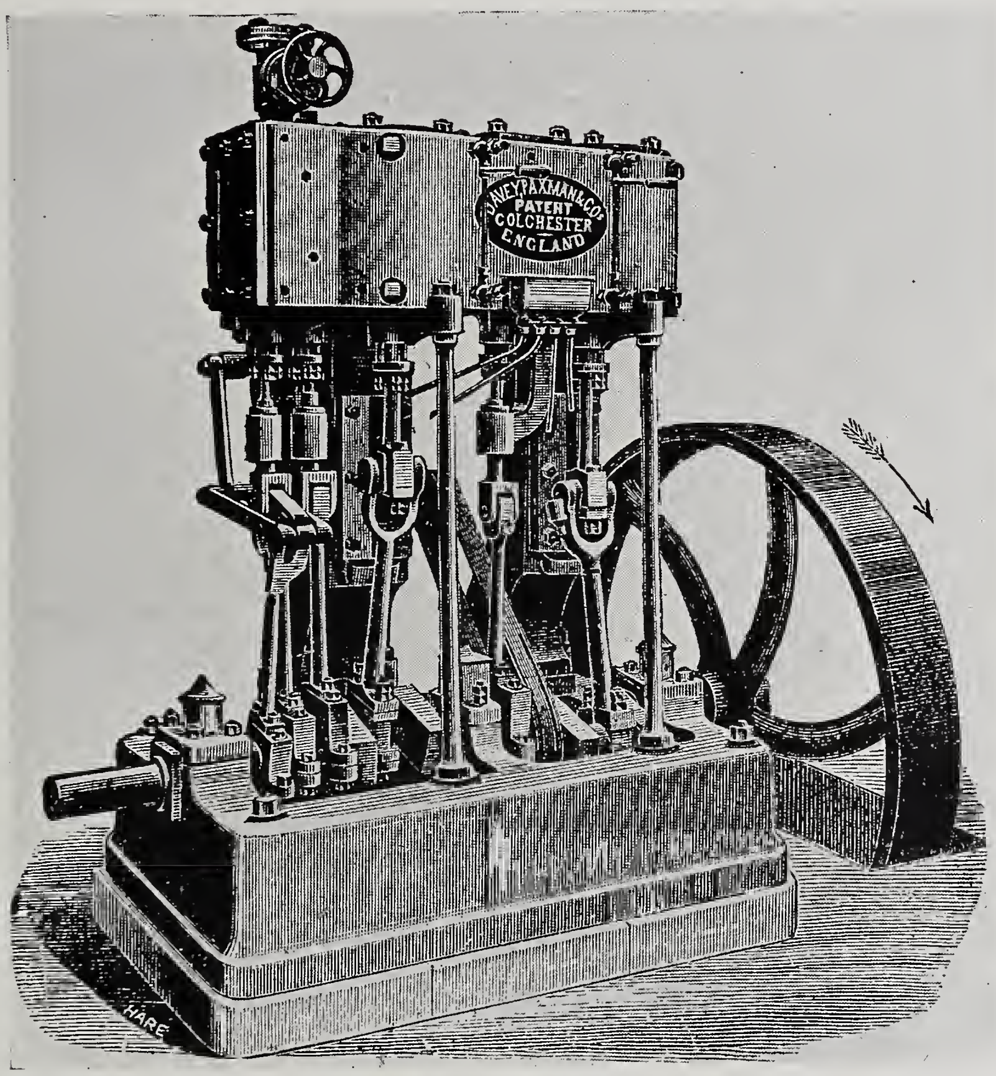
WILLANS ENGINE AND CROMPTON DYNAMO, AS USED IN ECCLESTON PLACE STATION OF WESTMINSTER ELECTRIC SUPPLY CORPORATION, LONDON.

(See page 186.)

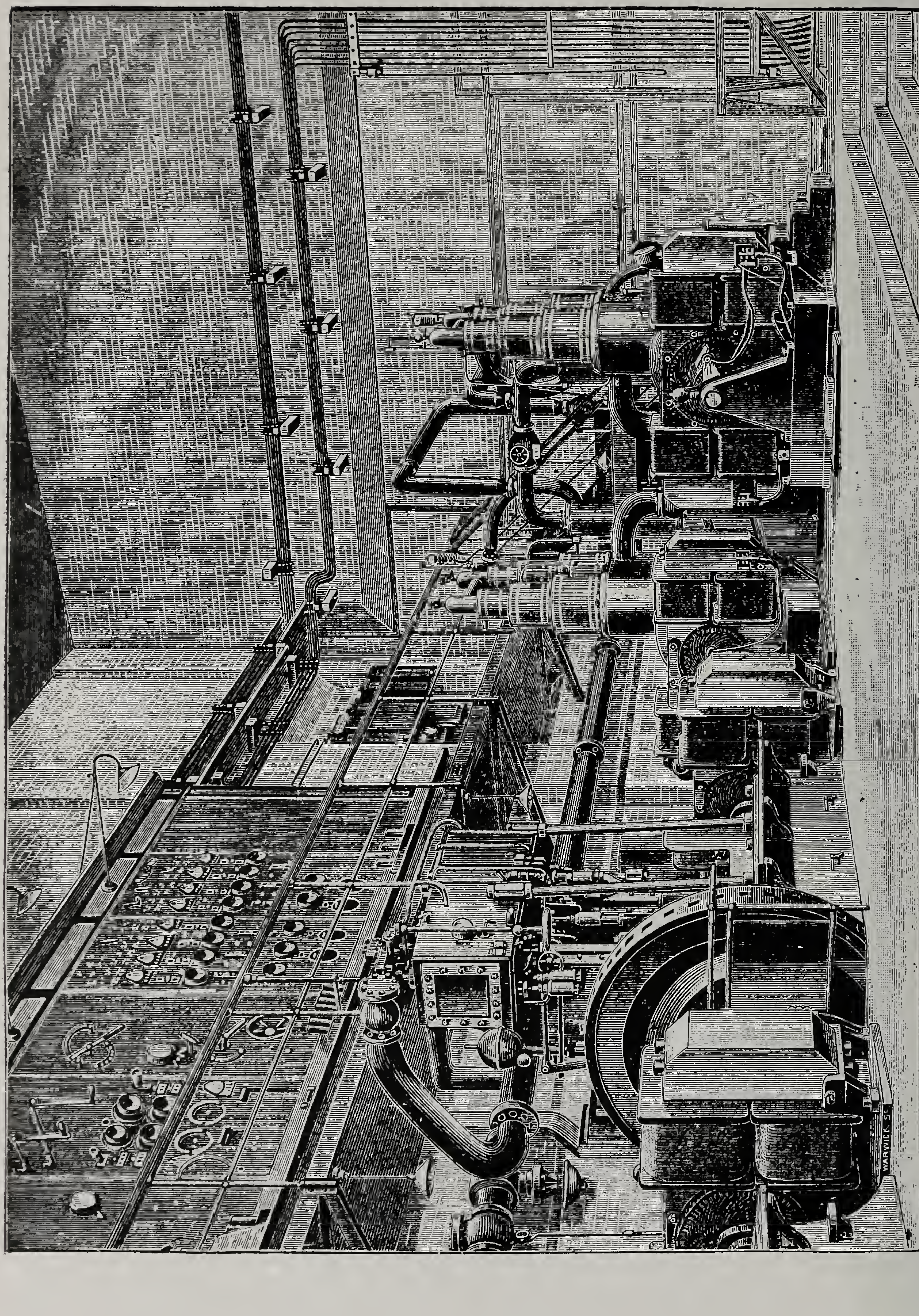
power, and the excellence of its governing allows the output to be perfectly controlled by shunt resistances. It is fitted with Paxman's automatic expansion gear and high-speed governors. With this gear the point of cut-off is varied automatically as required from 0 to 5/8ths of the stroke. The bedplate is in one piece, made of cast-iron. The cylinders are placed side by side, each being provided with separate steam chest and slide valve, and they are mounted on the top of cast-iron back standards and supported by steel columns in the front.

When the station is full of machinery, the steam exhaust will form a complete ring around the station. A condensing plant will soon be put in. The steam pipes are made of steel, with cast-iron stop valves, all the bends being of copper. Branch steam pipes are also of copper. In this station the marine type of boiler is used, not only for efficiency, but also for durability and facility of repairs.

Mr. Edwin H. Johnson, who was president of the Sprague Electric Motor Company until its absorption by the Edison Company, and who is now president of the Interior Conduit and Insulation Company, has lately turned his attention to direct-connected engines for electrical purposes. It is a well-established fact that if an engine be coupled direct to a dynamo, so that the armature takes the place of a fly-wheel, the combination will act perfectly well until the generator begins to approach its maximum capacity. Then the armature no longer acts as a fly-wheel, and the pulsations in the lamps are readily noticed.

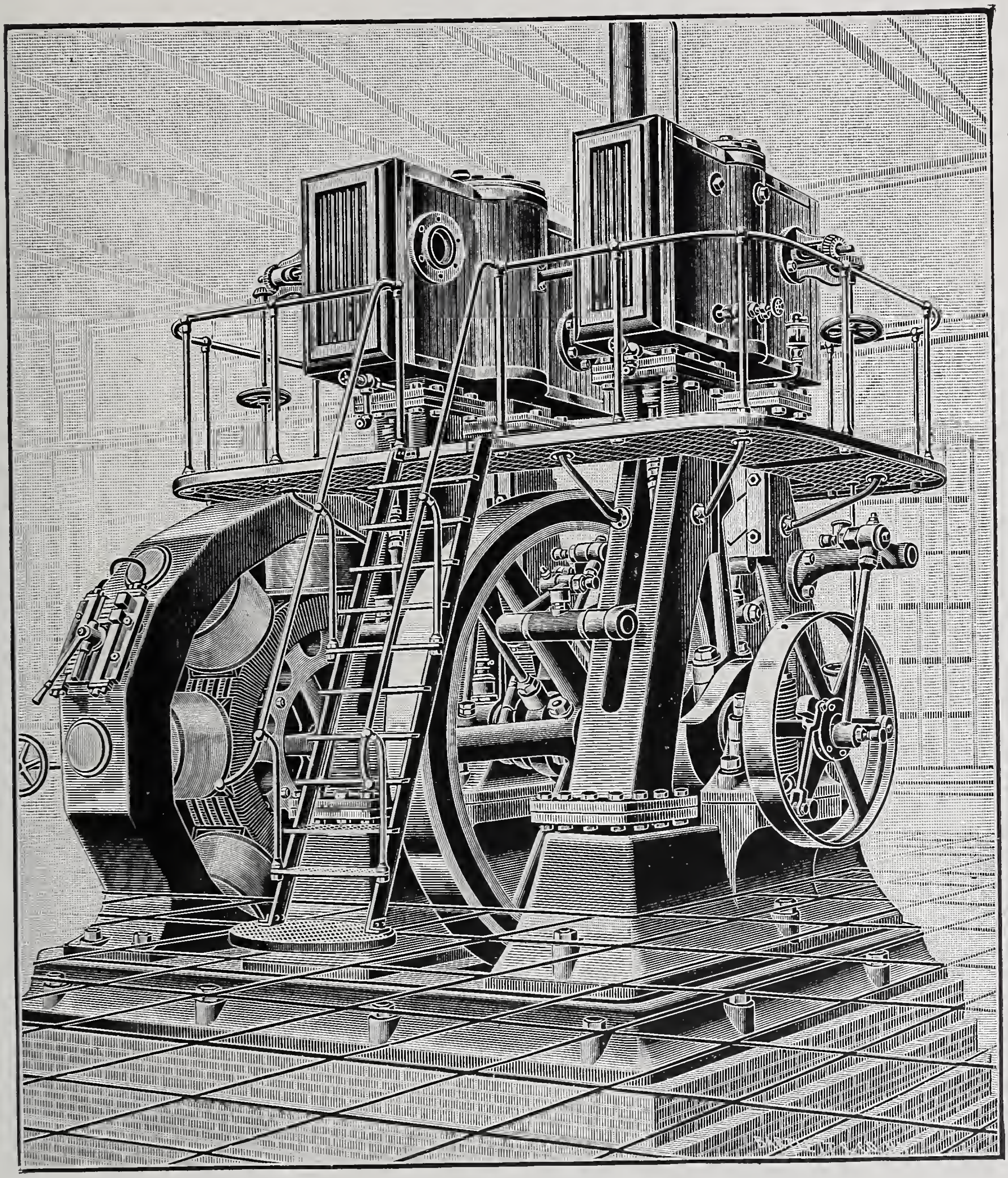


"WINDSOR" HIGH-SPEED ENGINE FOR DIRECT-CONNECTING WORK, MANUFACTURED BY DAVEY, PAXMAN & CO., COLCHESTER, ENGLAND.



INTERIOR OF ECCLESTON PLACE STATION OF THE WESTMINSTER ELECTRIC SUPPLY CORPORATION, LONDON, SHOWING WILLANS ENGINES ON THE RIGHT.

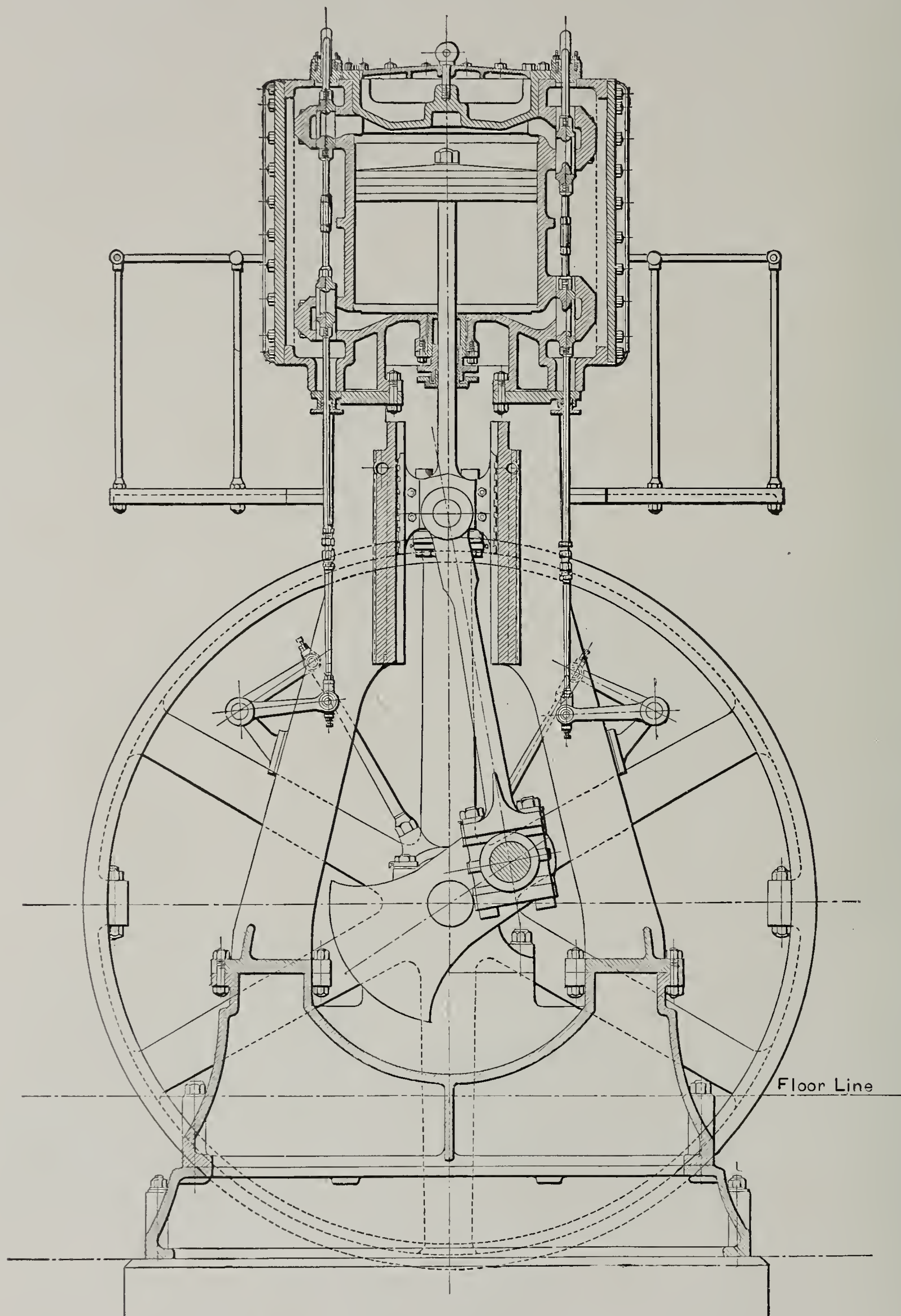
With this point in view, Mr. Johnson looked about for an economical, well-regulated, and compact high-speed engine, and finally decided to adopt the "straight-line." In this engine the two fly-wheels are placed between two bear-balance the weight of the fly-wheels on the inner side, thus also simplifying the construction. A special bedplate is provided, to which the dynamo can be bolted along with the engine. It is claimed that the generators in this com-



VERTICAL COMPOUND ENGINE AND EDISON DYNAMO; ENGINE DESIGNED BY LAKE ERIE ENGINEERING WORKS, BUFFALO, N. Y.

ings on the engine frame, thus affording the opportunity to attach a dynamo on each side of the engine direct to the shaft for electrical transmission by the three-wire system. Furthermore, this weight on the outer end of the shaft will bined plant will have a leakage of less than one per cent., thus obviating the necessity of carefully insulating them from the bedplate. This is rather remarkable in that what have generally been regarded as good machines have

a magnetic leakage varying from 30 to 40 per cent. In order to maintain a perfect magnet balance of the armature between the field magnets, a thrust-ting the armature fastened in its correct position on the shaft. It is in principle somewhat like the dial-plate of a milling machine. A plate which covers the end



DETAIL OF COMPOUND ENGINE BUILT BY LAKE ERIE ENGINEERING WORKS, BUFFALO, N. Y.

(See page 195.)

block, such as is used in marine practice, is placed between each dynamo and its fly-wheel. An ingenious arrangement has been devised for the purpose of get-

of the shaft and the hub of the armature has a number of holes bored into it, through which are inserted four bolts.

(To be continued.)

MACHINE MOLDING.*

By Harris Tabor.

OF all the mechanical arts, that of molding has been the most difficult to formulate and to reduce to a system. Since the origin of metal-founding the molder has been pleased to shroud his methods in certain mysteries, which, to him at least, seem essential to perfect castings. It may be said of this trade, more than any other, that the traditions of generations cling to it. Like the good housewife of the olden time whose bread was often sweet and delicious and occasionally intolerable, the man of rammer and trowel will alternately score success and failure under apparently the same conditions. He can always tell why his casting is good, but can rarely give a reason when it is bad. There is much which can be accounted for in this; perhaps, more that cannot be. In all other industrial branches the senses of touch and sight are always at the command of judgment. In the machine shop, contact between the workman and his work is always possible; an error may be detected as soon as made, and corrected at once; there are no final chances upon which the success of the machinist's job depends. With the molder it is different. The conditions which insure bad work, and cannot be anticipated, are numerous. There may have been a bar in the "cope" under enough tension to induce a "drop" when the additional "strain" of clamping was put on; the core, with which he had nothing to do beyond setting, may have been made with no reference to free "venting," and a "blow" follows pouring. His troubles do not end here; the melter may have been in a careless mood to the extent of dull iron, and a casting with "cold-shuts" is his reward; if his foreman make a wrong estimate on the amount of iron necessary to "pour" his mold, and give him too little, another loss will be charged to his account. There is much, beyond the control of the molder, in the art of metal-founding, which tends to make bad castings. His strongest influence upon the quality of his work lies in skill which cannot be verified by caliper, gage, or rule.

The molder's art is in making the mold of the proper density. Drawing a pattern from the sand after it has been rammed, and mending a broken mold, are mechanical operations easily taught. It is not so with ramming. If a touch of genius enter into molding, it is shown in making the mold of such density that it will stand pouring without "straining," and be soft enough to prevent "blowing" and "scabbing," with a certainty that the sand will remain in place until the iron has solidified. This is the molder's skill which cannot be formulated and passed down to succeeding generations, in books. It seems to be governed by an unwritten law which declares to him who would teach by theory, "Thou art not 'in it.'" Ramming a mold from the top to produce a required density on the under side may seem a simple operation to the layman, but a trial will convince him of one difficulty in molding. After he has learned to ram a flask with a given depth of sand, should he try one half as deep, he will discover his previous experience has not made him an all-around molder. This point is well illustrated in many large foundries doing duplicate work, where unskilled labor has been taught to mold a single pattern. In such cases, it is an invariable rule that it is not safe to change a man's work without putting him through a system of training on the new pattern. The writer has been told by foremen in such foundries that men who did excellent work on patterns which they had been taught to mold, were worthless on any other. In these cases the difficulty is in ramming and

* Paper read before the American Society of Mechanical Engineers.

pouring, principally in ramming. There can be no gage to determine the force of the rammer's blow. It is a question of experience supplemented by good judgment. Some men have a capacity for acquiring this skill beyond others, and they are slow to impart it. On this account we see a greater relative difference in the skill of molders than in any other trade, and it is for this reason that there are so few molders coming to take the place of the old school which is disappearing.

As a rule, the foundry has less support from the office than any other department. Its conveniences and comfort are the last to be considered. Nearly all members present can call to mind plenty of establishments where the machine shop is a model of excellence in the way of modern tools, is warmed to a comfortable temperature, and shows signs generally of a kind consideration for the workmen ; while the foundry is the same old kind with which we are familiar, filled with broken flasks, with no system of heating, and ventilated only through broken windows. There are no follow-boards or match-plates (the initial steps to machine molding) to cheapen processes. Even the core-boxes are misfits, and the work of filing cores to fit prints is equal to the cost of making the mold. There is a general air around the place which seems to indicate that the machine shop comes first, and the foundry last, in the affection of the manager. The foundry deserves a better consideration. It is here that the first step in machine construction is taken. It is here the first money is made ; in fact, in a majority of cases, the foundry is the telling factor in the financial success of the manufacturer of iron products.

There is no doubt but the difficulty in formulating the molder's practice has had much to do in withholding improvements from this department. Skepticism prevails, which is hard to overcome except by actual proof. In other departments a machine or fixture which has proven valuable in one shop may be sold to another on the strength of its record. In the foundry, success must be shown in the individual case before consideration is given. This doubt is gradually giving way under fierce competition. One year of low-priced castings will do more to set an iron founder thinking than a dozen years' experience with prices of his own making.

The development of machine molding has been gradual, covering a long period. The follow-board which covers, or shuts off, from the sand that portion of the

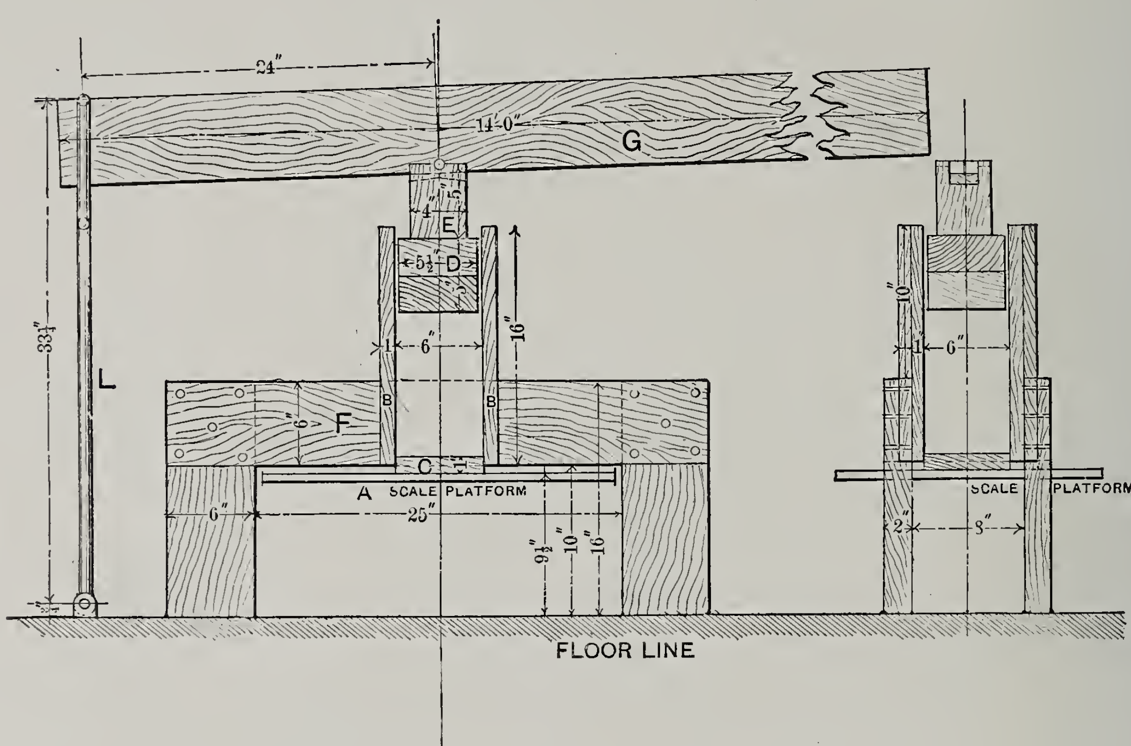


FIG. 142.

pattern above the joint line, was probably the first change from the original method of molding in boxes. The match-plate, which is a plate fitted with pins and pinholes for the flask, with a portion of the pattern fitted thereon like a medallion, came next. This was a greater improvement, for it compelled the flask to be interchangeable. Silhouette, or stripping-plates, followed with decided advantage. The stripping-plate, often called drop-plate, is a plate cut out to receive the outline of the pattern at the joint line; enough is added to the pattern to project through the plate to the pattern base. Like the match-plate it is fitted with pins and holes to receive the flask; it is also a molding table, or board on which the flasks are rammed. Originally, this plate was turned with the flask, and the pattern drawn through the plate by hand. Modifications of the stripping-plate are numerous, nearly all embodying a frame or table, with lever attachment for drawing the pattern without turning the flask. A good illustration of this type is the machine for molding pulleys.

The evolution of the power machine from the hand machine was natural. The deep-rooted prejudice on the part of the workman has had its effect on the development of so great an innovation in foundry methods, and its progress has been slow. There are, however, a number of excellent power machines on the market, operated, respectively, by belts and cams, hydraulic, pneumatic, and steam-pressure. It is not the purpose of this paper to discuss the merits of the various machines, but to touch upon some of the difficulties in the way of introducing machine molding in the foundry and the many advantages resulting therefrom, and incidentally a form of steam-operated machine with which the writer is identified.

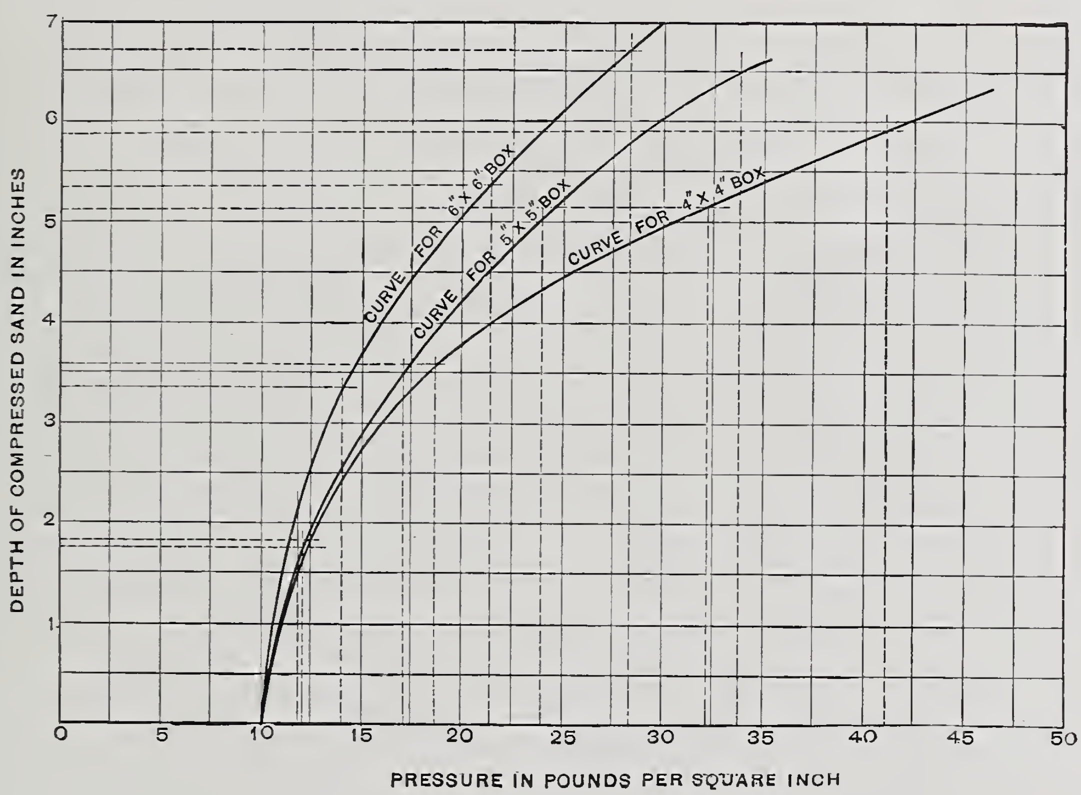


FIG. 143.

All ramming machines may be said to have platens, of which there are two types: rigid and flexible. The rigid platen is simply a block of sufficient size to cover the surface of sand in the flask; the flexible platen is one which yields to irregular depths of sand, and exerts a like pressure on all parts of the mold. Of the flexible platens there are two: (1) the water-bag, which is a rectangular box with a rubber diaphragm for the bottom, filled with water; (2) a group of rammers, equal in size to the flask to be rammed, hung on equalizing levers so that each rammer is independent of

its fellows. At first thought, the flexible platen would seem to be perfect. If sand, under pressure, flowed like water, and its required density over the pattern

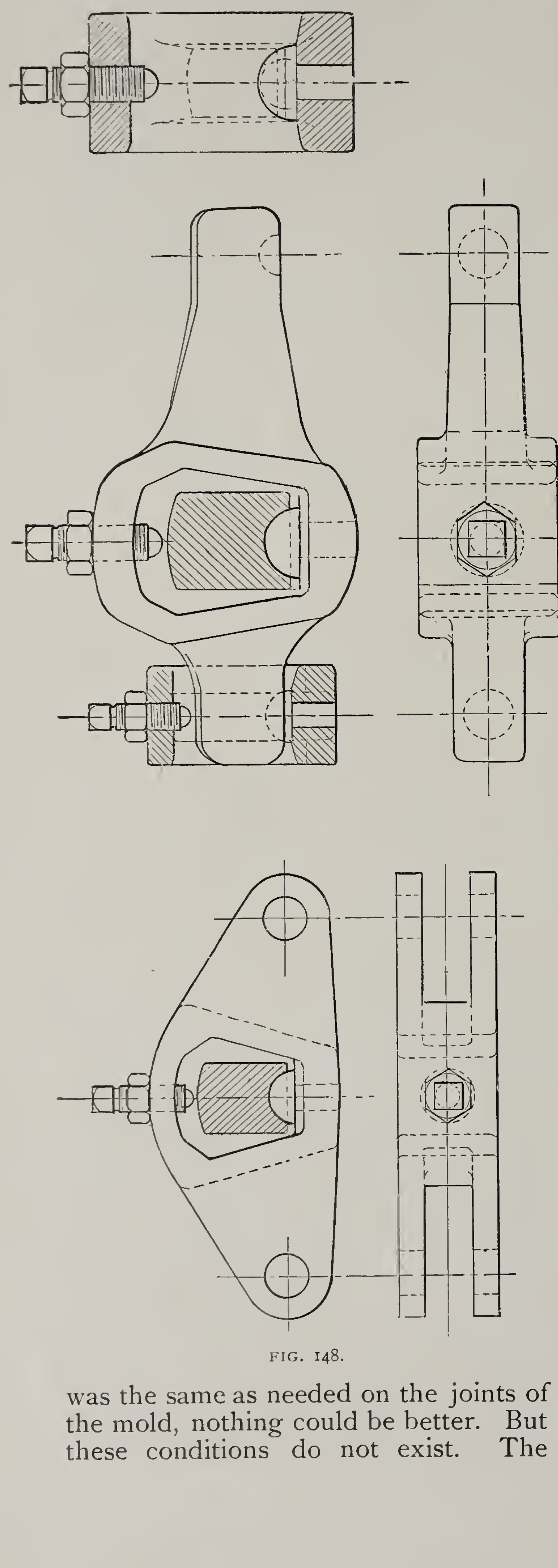


FIG. 148.

was the same as needed on the joints of the mold, nothing could be better. But these conditions do not exist. The friction of sand upon itself and upon the walls of the flask, makes it comparatively unresponsible when rammed by equal pressures ; if we add the fact that the mold, to pour well, should be softer over the iron than at the joints, we see that uniform pressure on a mold falls short of the requirements ; it is better, however, than the rigid platen, and requires much less hand-work in the way of ramming and tucking. As an evidence of the difficulty in making equal pressure suit all conditions, a case can be cited where we had a pattern projecting vertically about 6 inches in the sand ; at this point the side of the flask, which was 8 inches deep, came within 2 inches of the pattern. The average pressure, per square inch, over the mold was 40 lbs. ; the pressure put over the narrow belt of sand between the flask and pattern was 70 lbs. per square inch, leaving only 28 lbs. per square inch over the higher portion of pattern ; yet, notwithstanding the deep sand had 2½ times the pressure exerted over the lesser depths of the mold, it was necessary to precede the work of the machine rammers at this point by hand-tucking. This was an unusual case. It is true, in all cases, that more pressure is needed along the walls of the flask to overcome the friction of the sand ; hence we have found it necessary to arrange our rammers to produce this result, giving the marginal rammers about 50 per cent. more pressure. This does not always give perfect ramming, and occasionally it is necessary to do some hand-work, but, as a rule, this arrangement of rammers gives good results without hand manipulation.

In the spring of 1890, Mr. A. B. Moore, who was then a Stevens Institute senior, selected the rammer machine as the subject for his thesis. We discussed the lack of data bearing upon the friction of sand, and decided jointly to make experiments.

An ordinary platform-scale was used for weighing. A series of boxes, 4 x 4 inches, 5 x 5 inches, and 6 x 6 inches, was decided on ; these boxes were supported by frames spanning the scale and resting on the ground (Fig. 142) ; each box was fitted with a loose bottom which rested on the scale platform ; the

plunger used for ramming fitted its box loosely enough to avoid serious friction, and was connected to the weighted lever by a turned joint; the weight of the lever on the sand was found by weighing it in position. In all cases the scale was weighted to a pressure equal to 10 lbs. per square inch on the under face of the 2½ inches of loose sand were compressed to $1\frac{11}{16}$ inches to give a density equal to 10 lbs. pressure on the under side, and it required a pressure of 12½ lbs. on top of the sand to produce this result. With 5 inches of loose sand, 17½ lbs. pressure was required on top to give 10 lbs. below; an addition of 2½

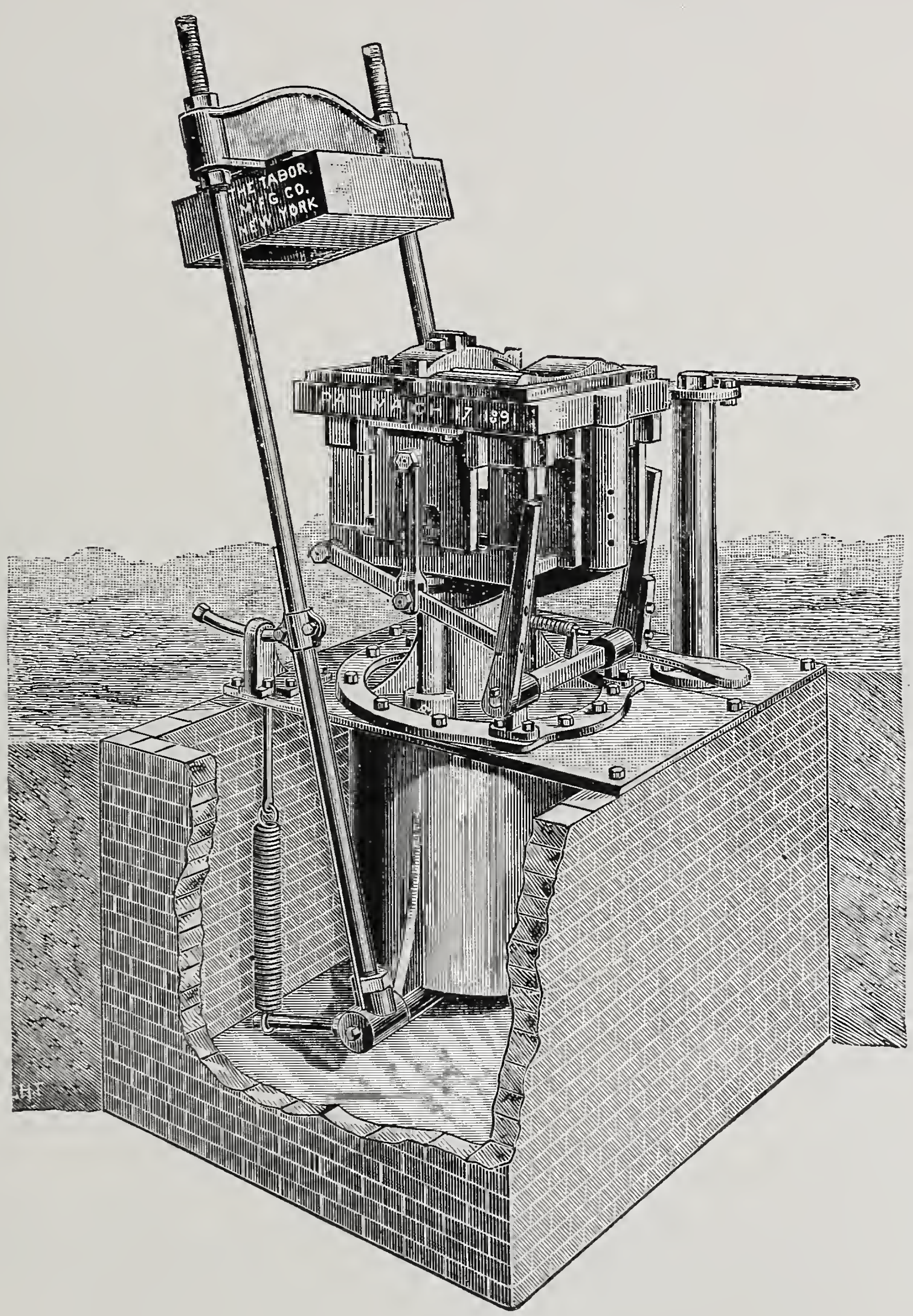


FIG. 144.

the box. (This is about the density of the average mold surface.) We began with the 4 inches square box as follows: 2½ inches of loose sand were put in and compressed until the scale-beam tipped; the intersection of the dotted line with 4 x 4-inch curve (Fig. 143) shows that inches in the depth of sand brought the ramming pressure up to 34 lbs., and the last 2½ inches (making 10 inches) required the pressure of 42 lbs. to give 10 lbs. on the scales. With the 6-inch box only 11½ lbs. were needed to give 10 below, with 2½ inches of sand; with 10

inches, 26 lbs. raised the scale-beam, or 16 lbs. less than was required, under precisely the same conditions, with the 4-inch box. The walls of the boxes were of undressed plank, to represent the average condition of wood flasks. The friction on iron sides would have been less.

There are several methods of anticipating unequal depths of sand in machine molding. With the rammer system greater pressure may be given over portions of the mold which would otherwise be too soft. When flasks are of such size that bars are necessary the rammers are arranged to straddle them, thus doing away with all tendency of the bars to spring ; this method also avoids the necessity of tucking under the bars. When the flat platen is used for ramming, sand may be scooped away from the higher portions of the pattern until the best result is obtained ; where the flasks are not too large, sand will flow sufficiently to give excellent results when this plan is followed. With all other automatic machines we use the rigid platen for ramming ; we make this of hard wood, which we cut out boldly over the pattern, and without much reference to the shape of the pattern ; the amount cut from the ramming head is about 50 per cent. more than the displacement of pattern for ordinary cases. By this method no skill or judgment is required in putting sand in the flask, and the density of mold over the iron may be made to suit any condition. On small work, up to flasks 24 inches square, we get the best results from this system. We have a method of using flask-bars for ramming, which seems to suit certain conditions better than other methods ; the bars are detached from the flask, and are made enough smaller so that they may be forced down without coming in contact with its walls ; the flask and sand-box are filled with sand, and the bars forced down by a flat platen ; the bars are deeper where the greatest ramming is required, and are made wedge-shaped at the bottom, so that one bar will spread the sand until it meets the spreading influence of its neighbor. With this plan it is sometimes necessary to use a bottom board on the drag, to hold the bars when the drag is turned ; the bars in the cope will hold in position against the pressure due to pouring.

An idea of the rammer connections may be obtained from the engraving showing details (Fig. 148) ; the rammers are hung to the ends of the cross-bars, which are grouped together by ball-joints and operated centrally by a steam piston. The flasks are placed on trucks, which are topped with stripping-plates and contain mechanism for drawing the pattern ; the trucks are run under the machine for ramming, and withdrawn to take off the mold and replace the flask.

A description of such an automatic machine (taken mainly from the columns of a technical journal*) may be conveniently introduced here to illustrate the operation of these principles :

Fig. 144 shows the floor broken to give a view of the machine below the floor line ; and Figs. 145 and 146 show sections made from working drawings. The piston takes steam on the under side only, its weight being sufficient to return it promptly after the mold is rammed.

To the piston-rod is attached the principal part of the mechanism, consisting of a table with lugs projecting upward, and supporting the pattern frame *B*, upon which rest the patterns ; the stripping-plate frame *A* directly over the pattern frame, and resting on it, to which the stripping-plate is attached ; the stool-plate *C* suspended to the stripping-plate frame, and moving with it ; side levers and tumbling shaft for stripping after the pattern is drawn. The pattern frame has an annular passage which is connected to the cylinder by the small pipe shown, the object of this being to admit some steam to the pattern-plate at each movement of the piston, this steam serving to keep the patterns moderately warm, preventing "sweating" or accumulation of moisture from the atmosphere, and making them draw from the sand more freely and smoothly. The stripping-plate frame is guided by two bored sockets, one at the front, and the other at the

* *American Machinist*, of New York, October 22, 1891.

back of the machine, there being air-holes below the pistons, by which any desired amount of cushion can be obtained for the drop of the stripping-plate frame. The stool-plate is really part of the stripping-plate frame placed

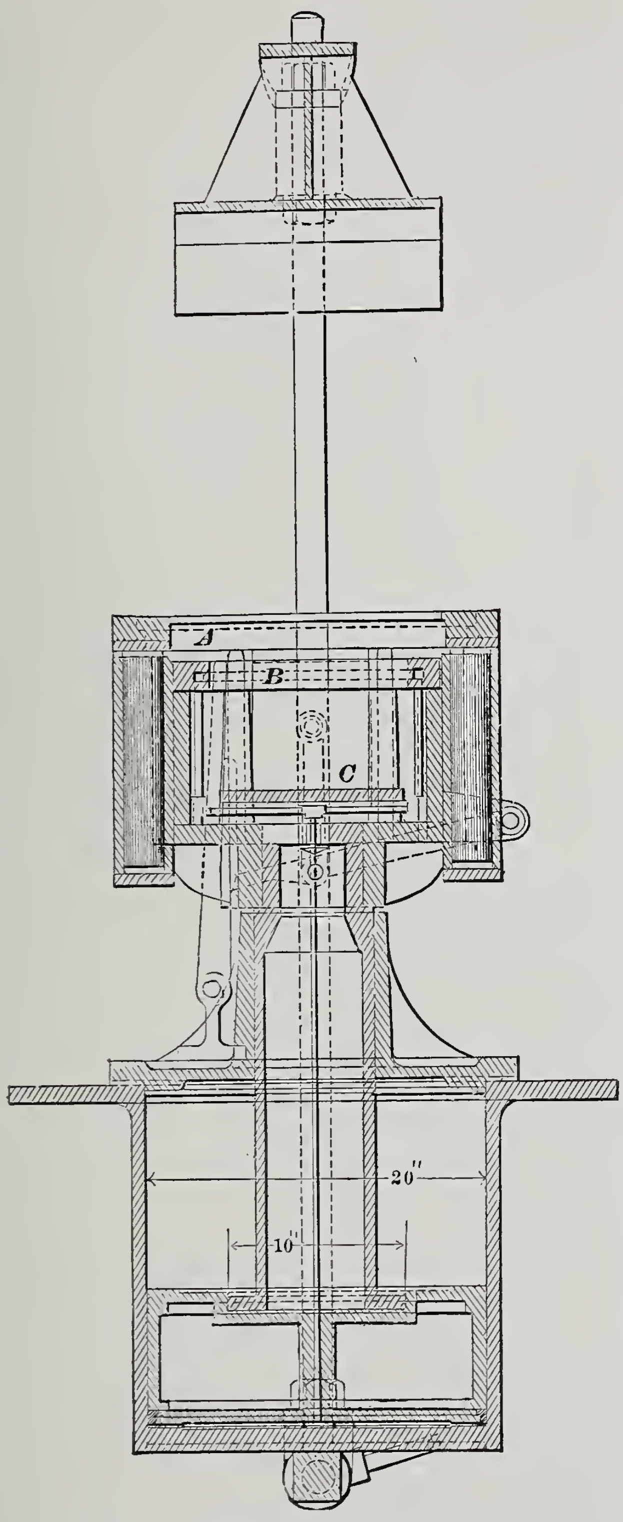


FIG. 145.

below the pattern frame, and its object is to support stools or internal parts of the stripping-plate used in holding green sand cores, or heavy bodies of hanging sand, while the pattern is being drawn. The side levers are pivoted at one end to the table, and are connected at the middle, by links, to the stripping-plate frame, the outer end being free. The tumbling or tripping shaft is in front of the machine, near the floor, and has arms projecting upward along the line of travel followed by the free ends of the side levers; on these arms are stops which engage with the free ends of the levers on the downward motion, to draw the pattern.

The ramming head is carried by the wrought rods seen at either side of the machine, these being attached to a horizontal shaft at the bottom of the cylinder, which allows them to be swung forward and back as shown, a spiral spring being used to counterbalance the weight. The ramming head is usually of wood, roughly cut out over the pattern, to avoid too hard ramming on the high places. This block may, of course, be readily changed to suit any flask within the capacity of the machine. The stops on the stripping-plate can be also changed to suit any pattern within the range of the machine. The steam pipe enters the cylinder at the bottom, and from the throttle-valve to the cylinder serves also as an exhaust-pipe, the throttle-valve being a two-way cock by which steam is either admitted or exhausted from the cylinder.

The operation of the machine is very simple. The half flask is put on the stripping-plate, with the sand-box to hold the sand which is to be compressed, and both are filled with sand. The ramming head is then swung forward over the flask against stops which define its position, and the throttle-valve opened. The upward motion of the piston and attached parts carries the flask and sand up to the ramming head, where it is rammed instantly, and upon the throttle-valve lever being moved again, steam is cut off, and at the same time exhausted, allowing the flask to descend; the stops then engaging the free end of side levers, and arresting the downward motion of the stripping-plate at a point about midway; the pattern, continuing to descend, is drawn from the mold, and when the piston has returned to its lowest position the sand

is struck off the flask, which is then taken from the machine. As the man removes it he presses the tripping treadle with his foot to release the tripping-plate frame, which then falls to its proper position with respect to the pat-

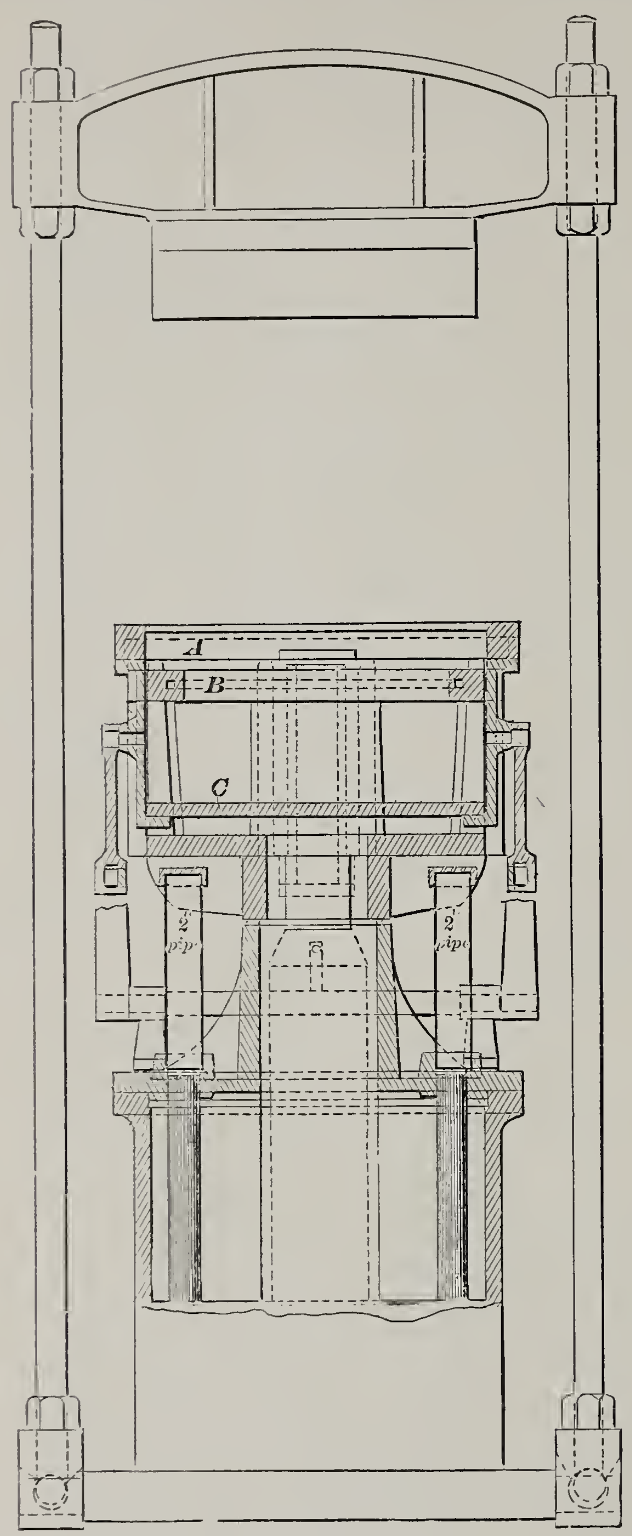


FIG. 146.

tern, and the machine is then ready for another mold.

Water or compressed air may be used instead of steam, if it is desirable, though it is believed that steam is preferable in most cases; because it is usually easily obtained without the use of other special auxiliary machinery of any kind; it is cheaper, and the steam appliances coming under the charge of the fireman or engineer, the foundry is relieved of the care of them.

Good molding machines in a foundry where there is a fair amount of duplicate work may be made as profitable as the turret lathe has been in the machine shop. It has been said of the turret lathe that its limit is set by the ingenuity of the tool-maker. If pattern-maker be substituted for tool-maker, and a fair amount of "nerve" in foreman be added, the same may be said of the molding machine. Like the turret lathe, its best results are obtained when operated by unskilled labor, or men trained only in the use of the machine. When the foreman has a reasonable amount of patience at the start, coupled with a disposition to make good castings cheaply, there is no doubt of his success in machine molding. If these qualities are lacking, it is better to defer the introduction of machines until the foreman has been brought to see their advantages, or has been supplanted by a more progressive man. We have a case where the manager of a large iron foundry came to see a machine making castings similar to his own. He was especially interested when he saw a duplicate of one of his patterns on the machine, and tons of machine-made castings in the yard for his inspection. There was no doubt, in his mind, of the value of molding machines in his business, and he wanted to introduce them. The question was left to his foreman, who decided against the purchase after seeing a machine in operation, and admitting the work was much better and cheaper than he could produce by hand. Here was a case where prejudice, or fear of a change in methods, overruled judgment. In another case, parties who are engaged in a competitive business, noted for low-priced castings, sent their foreman on a similar mission; on his return he insisted that one be furnished him, and their order for a machine followed. We have one more instance on record of a foreman demanding machines. Such cases, however, are not the rule.

If a builder of machine tools sells a machine under a guarantee that it will produce given results, and the purchaser fails to get them, the maker can send man to make good his claim if the machine is as advertised. This cannot be said of molding machines. There are so many conditions and operations in the process of making castings, independent of the mold, which have their influence, that the molding-machine vendor cannot verify his work in any foundry but his own unless he have the hearty co-operation of the foreman. The most perfect mold may be ruined in pouring; a defective core may produce a blow for which an innocent machine would get credit; a vicious kick given to a flask might cause a drop of sand, and a handful of dirt dropped in the pouring hole will spoil what otherwise would have been a perfect casting. These are conditions beyond the reach of the molding-machine maker; and, if they exist, and he cannot have the support of the foreman, his case in that particular foundry is hopeless. But when he can count on the same encouragement that is given to the machine-tool maker by the machine shop, his showing will be quite as good.

Consideration has not always influenced the introduction of molding machines. Unlike all other merchandise, they should not be sold by the purely commercial man. The seller must have a fair knowledge of molding and general foundry work if he would avoid serious trouble; he must understand first, and all the time, that it is better to lose a sale than to place a machine where conditions are against its success. In too many cases cumbersome power machines that are slow in operation and expensive to handle, have been recommended to do work that should have gone on a different machine, or been left to the molder's rammer. There are plenty of foundries in the country making a specialty of light bench-work that could not afford to use our rammer machines; but in these foundries our automatics would make a wonderful reduction in the cost of molding.

It is a mistaken notion that stripping-plates and metal patterns must be used on power machines. In 1887 we sold a twenty-four-inch rammer machine to parties operating a steel foundry. Each year since they have ordered more machines, and now they have eight, varying in size from 18 x 18 to 44 x 44 inches. Much of the time these machines are run night and day. Not more than two, and probably only one, have ever had a stripping-plate. There is nothing special in their business to warrant expensive patterns. Their work is general, and usually made from patterns sent them. If an order comes for twenty-five castings from one pattern, they at once scheme to get it on a machine, and generally with success. They keep on hand boards fitted with pins and pinholes to match their flasks, on which they dowel the pattern, each half going on a board. These boards are placed on the machine truck, with the flask over them, filled with sand and rammed under the machine. The pattern, of course, is drawn by hand. Each machine is operated entirely by laborers; one, brighter than the others, has charge of the machine and draws the patterns. When the 44 x 44-inch machine was in the course of construction, the superintendent of this foundry happened to be in the shop. He saw this machine on the floor and said that he was just finishing an order for fifty castings, weighing 1500 pounds each, and that he would have made them all on this machine if it had been in his foundry. I have never seen an instance where machine molding is so generally used as in this case.

The all-absorbing question, What is the economy in machine molding? is very difficult to answer. The product of machines will vary in different foundries, as much as the product of the molder. What may be called a fair day's work is an unsettled question. From the standpoint of manufacturer and workman it is too small in some localities, and too great in others. A machine that will mold 175 flasks, 16 x 16 x 10 inches deep, with two men to operate it, in one foundry, would, under precisely the same conditions, mold 250 in another. One manager may surround his machine with little conveniences for handling work, and thus increase his product, while another would compel the machine men to work under

disadvantages. The treasurer and practical shop man of a foundry were observing the operation of an automatic machine, with watch in hand ; a complete half mold in 16-inch nowel, or as they would say out West, drag, 5 inches deep, had just been made and turned on the floor for inspection in ten seconds after the sand was put in the flask, when the treasurer asked the question, "How many molds can be made in a day?" Before the writer could reply the shop man said, "That is not the question ; the question is, How many molds can we take care of?" A better answer could not have been given. The first machine of our automatic type has been in use about a year. The conditions are not favorable ; all the sand is handled by shovels, and the flasks and molds are carried to and from the machine by hand. The flasks used in this case are 14 x 17 x 10 inches deep, and weigh 70 pounds. The sand in flask, when rammed, weighs 156 pounds. The two men on this machine make 200 molds per day, and average during the working-hours from 27 to 34 molds per hour. These men have made and carried away 158 nowels in one hour and thirty-five minutes, and have made 200 complete molds, ready for clamping, in less than five hours. We must keep in mind that these two men must shovel into flasks over 31,000 pounds of sand, and carry off the same amount, in making 200 molds ; they must also handle twice 14,000 pounds of iron in flasks. 200 molds, under these conditions, is too much for five hours' work.

But this number is not too much for a day's work for two men.. A greater product might be obtained from an additional man, or from a conveyor for elevating sand to a hopper over the machine. A system of handling the molds after they are made would also add to the machine's capacity.

ELECTRICAL EQUIPMENT OF MODERN WARSHIPS.—II.

By H. Hutchins, Lieutenant U.S.N.

SHIPS for war, as has been noted in a previous article on the subject, require a great variety of electrical apparatus in order to meet the modern necessities. The main problem is to supply the amount of electrical energy demanded when fighting or manœuvering the ship; and not only this, but to take every precaution to prevent an interruption of the supply during battle. The fighting efficiency outweighs all other considerations. It is in time of battle that the total amount of energy liable to be wanted at any instant reaches a maximum. For instance, at night-time, there would be in operation all the search-lights, the greater portion of the incandescent lights below decks, it will be perceived that the principal requirements in installing the system are to obtain the necessary energy with a minimum weight, minimum space, and, above all things, maximum reliability. This is merely in accordance with the one idea which obtains in the designing of war ships,—that is, to get the greatest amount of offensive power possible on a given displacement allowed. The defensive power, the principal feature of which is the armor protection, is also a requirement, but in a lesser degree—for ships are built to fight, not to run away—nor should be.

It depends on the duty the vessel is to perform what shall be her type; in other words, whether the speed shall be in excess or the battery power. Compromises must be made in any one vessel, and the relative importance of battery power, speed, and armor, or other protection, decided upon according as is desirable. For instance, to increase the battery, would mean an increase of weight, and as the total weight is limited in order that the calculated draught may not be exceeded, either the speed or the armor protection, or both, must be decreased. This is why it is so important to economize weight and space, even with the electrical equipment, for any little saving in this direction means that the ship can carry a few more rounds of ammunition, perhaps, or a little more armor. The result of an action even between two ships of equal size might be due to the fact that the weight saved in the electrical and other parts of the equipment of the vessel allowed the victor to carry two or three more guns than her adversary, providing of course that both vessels' guns were of equal penetrating power and could be fired an equal number of times per minute.

The great bulk of the numerous devices found on board ship that consume electrical energy are fed by the dynamos, the dynamo room being practically a central station. In this system the principal consumers of energy are the incandescent lamp, the search-light, and the electric motor.

In addition to the electric light plant, primary batteries are also a necessary part of the outfit. They are located in different parts of the ship and the nature of the work determines whether or not the systems shall be entirely independent of each other and also governs the size and arrangement of the batteries. In the systems worked by primary batteries may be included the numerous call bells, telephones, fire alarms, water alarms, range finders, range telegraphs, engine room telegraphs and indicators, steering telegraphs and indicators, torpedo and gun-firing circuits, etc. For most of this work the Leclanché cells are better adapted than any others. They require but little attention and their endurance is practically unlimited. Many of the various forms of dry bat-

teries, for which so much is claimed, have been tried but have in nearly every case proven unreliable after a short time. If the dynamo current is used for this work, the higher voltage requires that the devices be specially made for it or wasteful resistances introduced, and then again a much higher grade of insulation throughout these circuits would be necessary. Moreover if the dynamo current is to be employed the system must have the same protection in the way of safety fuses, etc., as the electric light plant. Again a leaky steam joint between the boiler and dynamo room, or a slight accident to the dynamo engine might render the devices on these circuits useless at a critical moment.

Storage batteries are sometimes employed as best adapted for certain work in place of primary batteries ; but more generally they are used to help out the dynamos in supplying light and power. In some vessels the storage battery is installed as an adjunct to the electric light plant, but for many reasons which it is a question whether such an arrangement is economical or even desirable. In connection with the electric motor the storage battery finds its best field, up to the present time, as a means of propelling submarine boats.

In making repairs by using the electric light certain parts of the vessel are rendered accessible, which would not be the case with the oil lamp ; and moreover repairs can go on by night if desired, as well as by day, both outside of the vessel as well as to the inside, as for instance in submarine diving to allow of examination of the ship's bottom, (See Fig. 2).

DYNAMO ROOM ON BOARD OF U.S.S. MIANTONOMAH.

Another important use of electricity on shipboard is for indicating a signal from one vessel to another.

The illustration in Fig. 1 shows an engraving made from drawings of the White Squadron, exchanging signals, the particular signal shown being indicated by five lights.

The transmission of energy by electricity possesses two general advantages over any other system—in being more economical when energy is to be transmitted over a long distance, or when it is to be subdivided into a number of paths. The former has no application on shipboard, as the distances are short, but the latter meets many of the conditions for a modern navy. A modern cruiser contains numerous small steam engines scattered all over the vessel and used for auxiliary purposes, and just here lies the field for the electric motor. This, however, necessitates an additional loss by the double conversion in dynamo and motor, amounting to at least 20 per cent., to say nothing of the cost of dynamo and motor, so that this system would be uneconomical if the power is required at but one place as compared to the plan of placing a steam engine at the point where the work is to be done. But where the power is required at numerous parts of the vessel the case is different. The motor has the advantage on the grounds of economy for this reason, that small motors and dynamos are more economical compared to large ones than small steam engines are. Then again, the loss in transmission is slight. Add to this the fact that the dynamo room can be located in a fairly central position, say just forward of the boilers (but in the next compartment), and in it concentrate much of the auxiliary power of the ship in the shape of large, economical compound condensing engines driving high efficiency dynamos directly connected. The advantage of the electric motor would seem to be apparent.

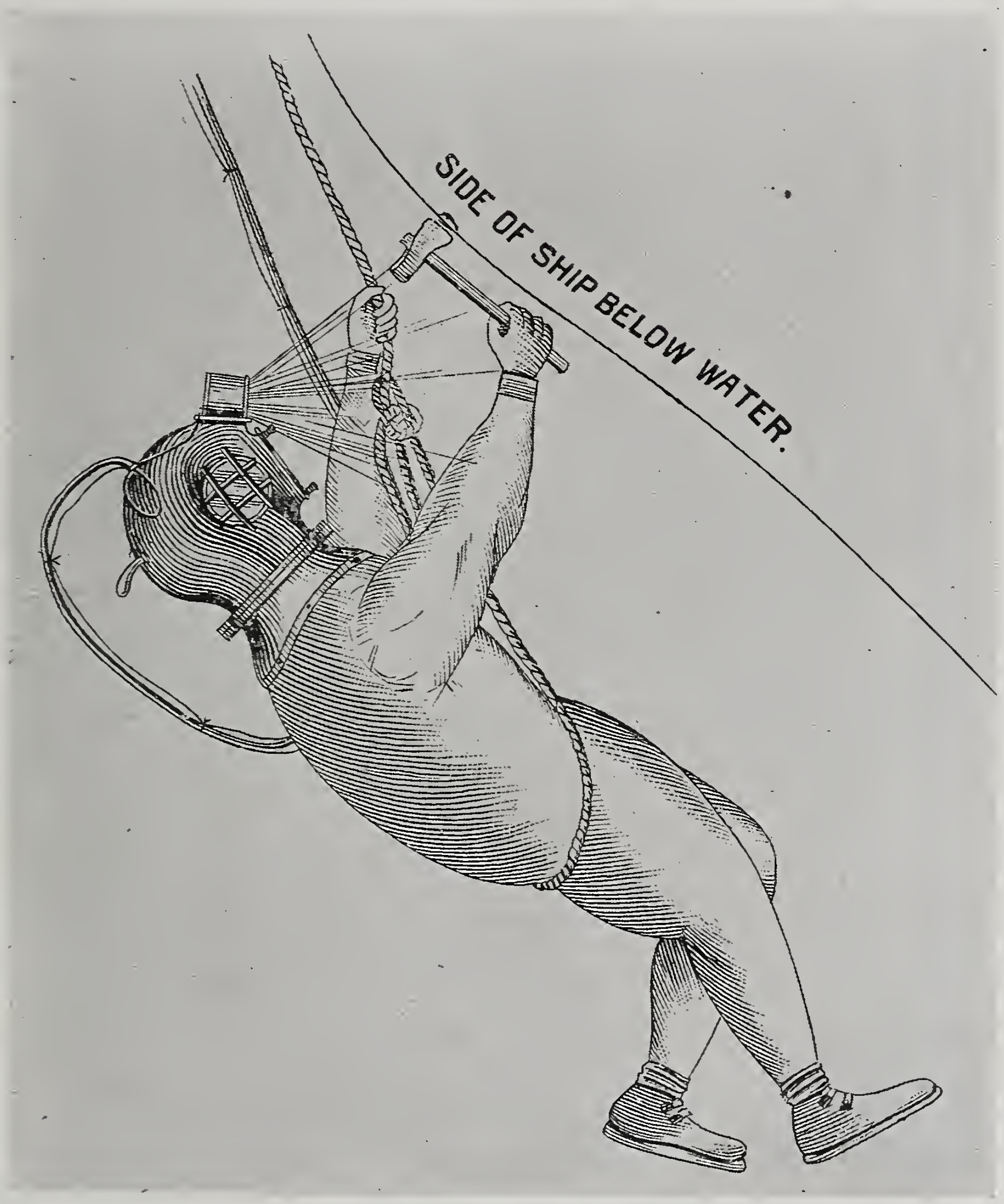


FIG. 2. SHOWING THE USE OF ELECTRICITY IN SUB-MARINE WORK.

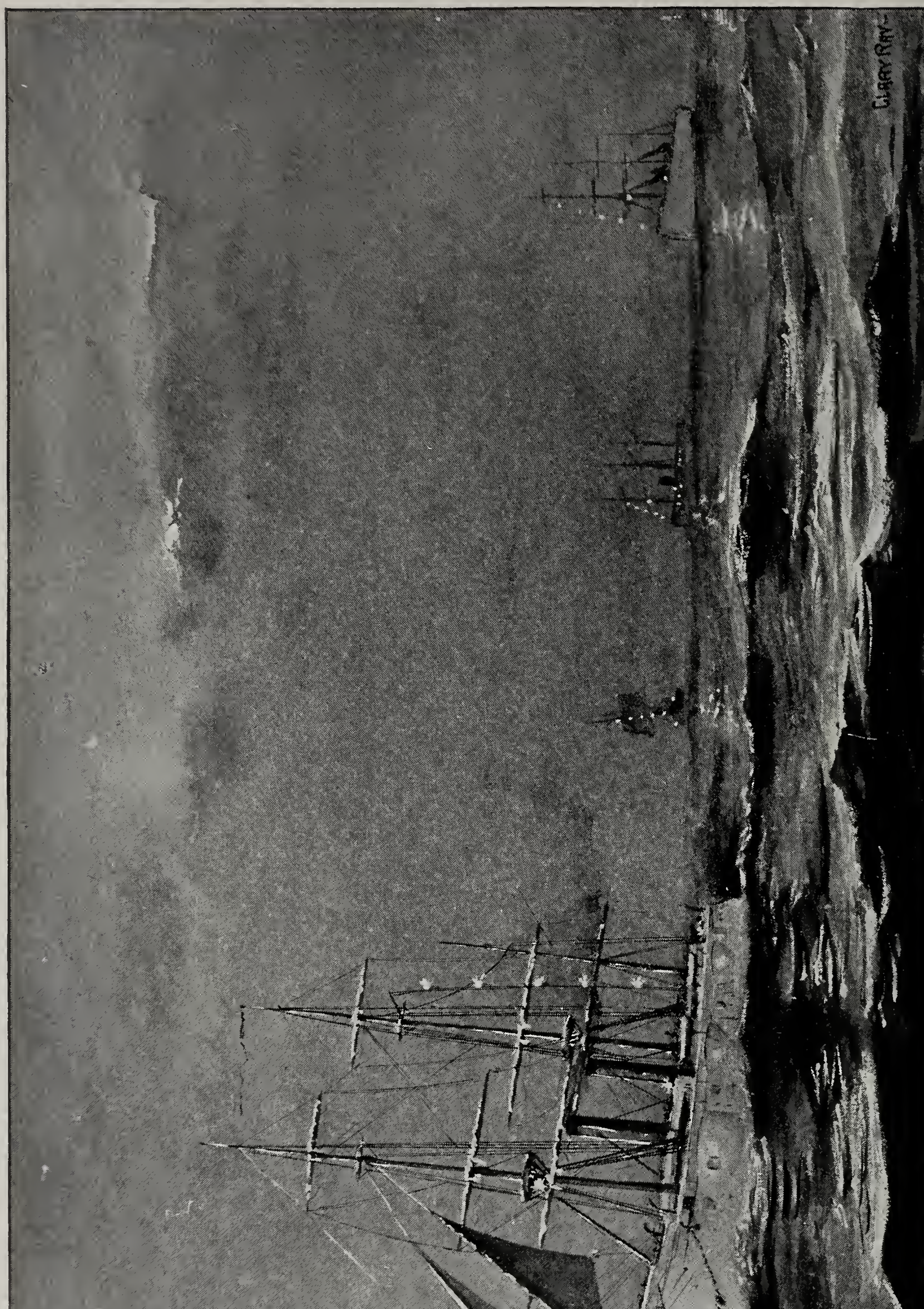


FIG. 1. SIGNALING WITH ELECTRICITY AT SEA.

The mains over which the energy is transmitted to the motor are smaller than the steam engine, and hence are less liable to injury. Besides, they admit of being more rapidly repaired than steam pipes in case of injury. Moreover, there is no danger in the low potential used on shipboard, whereas it may be quite the opposite in the case of steam escaping from an injured pipe. The motor, then, is evidently more reliable.

The uses to which electric motors have so far been applied on ship board are, driving ventilating fans, training of guns (large and small), controlling the fire of machine guns (the motor being employed to turn the crank instead of requiring another man), working the search-light projectors, hoisting ammunition, operating the steering engine, working electric drills, small pumps. winches, ete.

A neat application of the electric

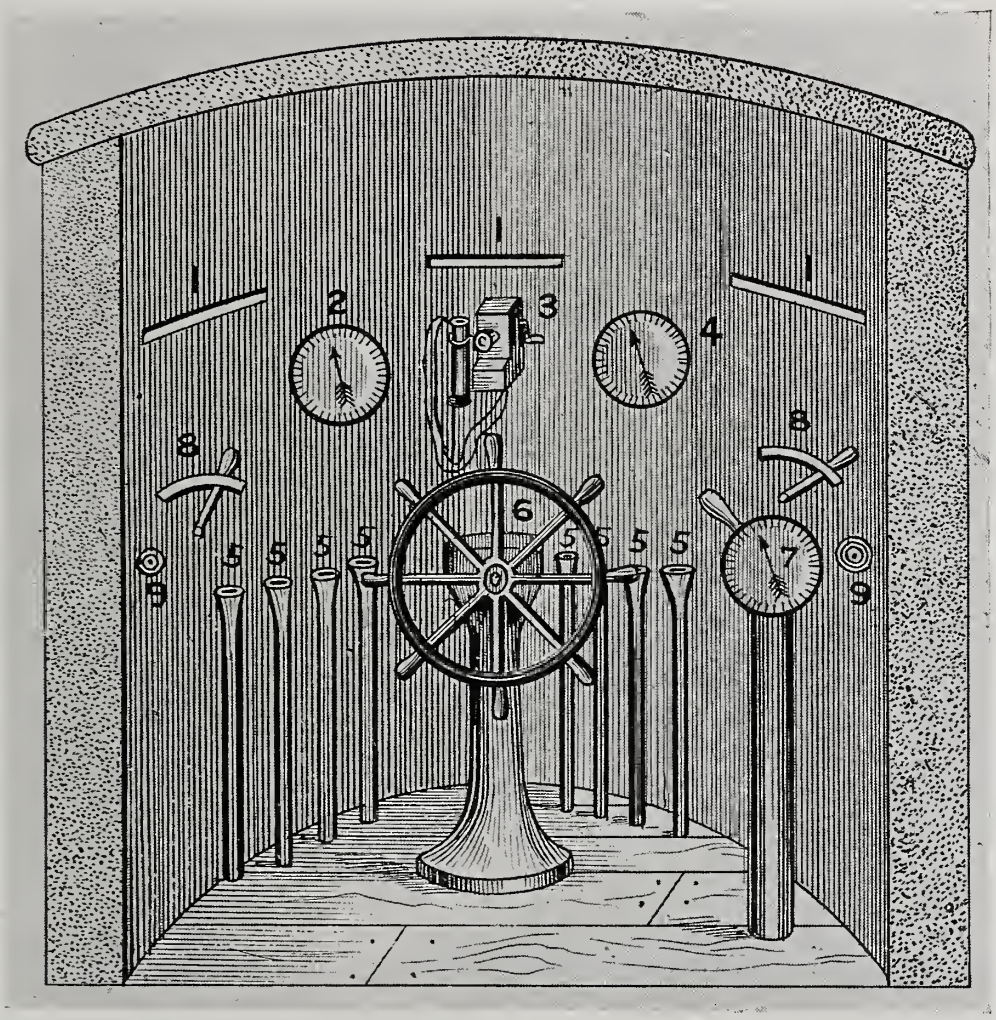


FIG. 3. CONNING TOWER, THE CAPTAIN'S STATION DURING ACTION.

Then again, the heat, dirt, and noise arising from small steam engines is very objectionable.

As regards weight and space, the advantage of the motor is not so apparent, as the weight of the steam engine and its piping has to be compared, not only with the motor and its mains, but, in addition, the increase in the generating plant. In ships of much size, however, a little extra weight or space is easily obtained, and, if necessary, reductions made elsewhere to compensate.

motor has recently been made on board the "Miantonomah," one of our reconstructed monitors, though in fact the first and only real fighting ship belonging to the new navy. Each of her two turrets carries two 10 inch breech-loading rifles. It was thought that a motor fan, placed in rear of one of these guns, and operated as a branch circuit from the lighting plant, would perhaps do away with the inconvenience of having the turret filled with smoke due to the discharge. Accordingly a 1/6 H.P. Crocker-

Wheeler motor with fan attached, wound for 80 volts and protected by a wire guard, was placed on a shelf in the rear of the gun and inclined so that the shaft of the armature pointed to the breech of the gun when in the loading position ; the distance being about 6 feet. The blast at the breech was apparently strong enough to answer its purpose of preventing the entrance of smoke into the turret, there being a draught through the gun sufficiently powerful at the muzzle to blow out a handkerchief held in front of it. The result was that each of the four guns was permanently provided with one of these arrangements. Even if smoke should enter the turret, the motor would keep the space in rear of the breech clear.

There are however many conditions where electricity is not by any means the most suitable agent to employ, and such will often be the case. Weight, space, simplicity, economy, and, above all, reliability are the points which must ever be kept in mind. It is the aim of the naval officer, when the ship is designed, to provide that source of power which is best adapted to fulfill the above requirements, to see that the apparatus when constructed is capable of doing the work which the conditions impose, and afterwards to handle the apparatus himself to the best advantage. The electrical as well as the other machinery and weapons necessary for fighting and maneuvering the ship are concentrated in the hands of one man, the captain, whose station in action is in the conning tower, (See Fig. 3). This tower is a circular chamber about 6 feet in diameter, the sides and the roof both being heavily armored with solid steel.

The position of this tower in the vessel is well forward, in the vicinity of and generally underneath the forward bridge. Numerous appliances diminish the scanty space which it affords on the inside, among which are the steering-wheel, binnacle, speaking tubes, press buttons, and various telegraphs and indicators connected with the working of the engines, rudder, etc. Here in this spot is concentrated the whole power of the tremendous "machine" which is called an ironclad ship. The captain has but to press a button to start at a 20-knot speed the great engines driving the twin screws. He has but to press another button to start the torpedoes on their way at a speed of 30 miles an hour. Another signal, and the big guns belch forth and discharge their enormous weight of metal. Move a switch, and the search-lights give forth their powerful beams of 40,000 candles. Another signal, and preparations are made to use that other terrible weapon, the ram. Picture to yourself how great must be the strain upon the nerve and judgment of the commander in action. Thus we see how the development of the modern war ships has brought about the usefulness of electrical energy.

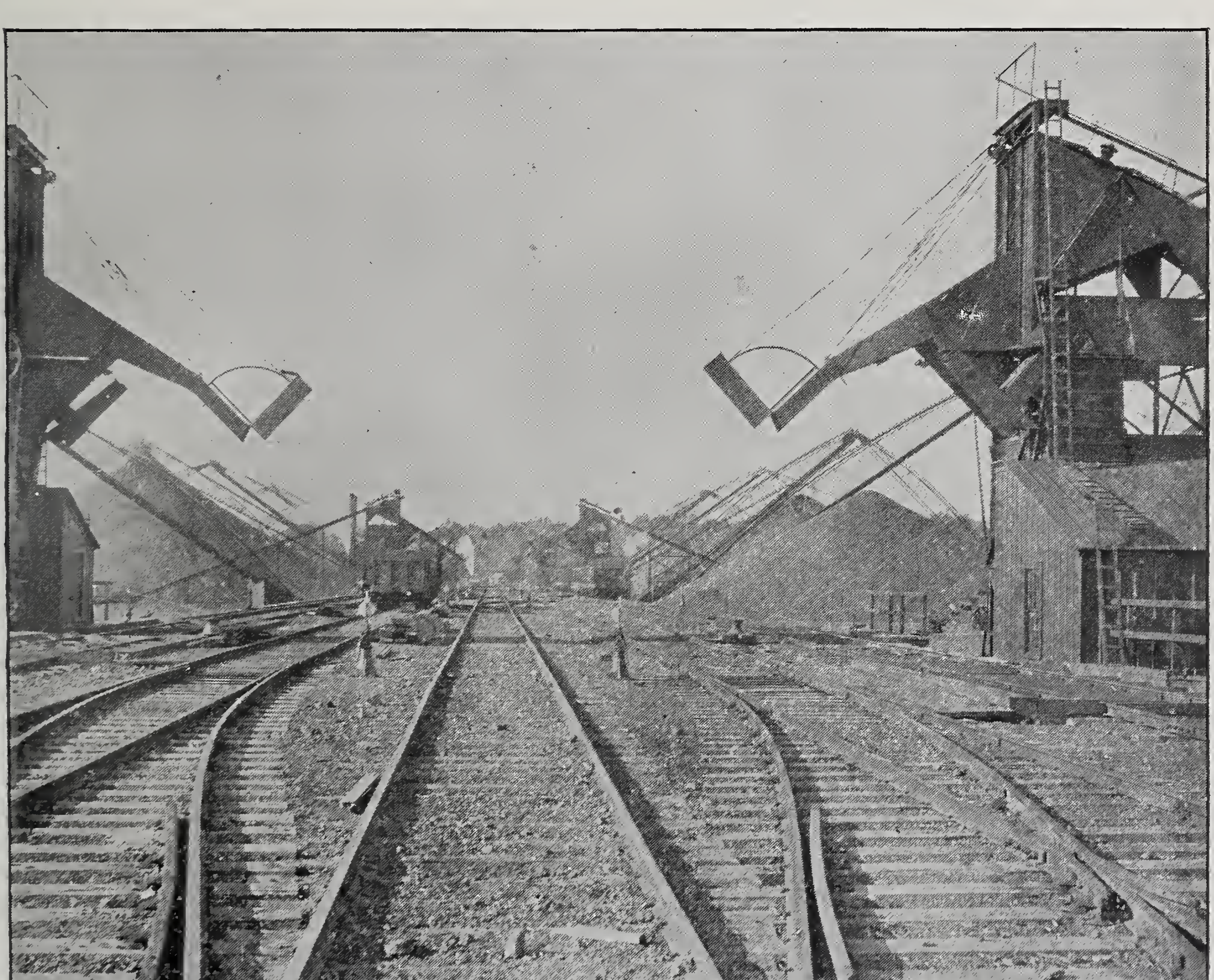
It is reserved for another article to describe the system of distributing all this energy throughout the ship, the apparatus of the most improved type that is in actual use, together with the manner in which it is operated.

MODERN METHODS OF STORING COAL.

By Thomas W. Milnor, M.E.

IN describing the installation of the Lehigh Valley Railroad Company at South Plainfield, New Jersey, for the handling and storing of anthracite coal, it may be of interest to give a short historical sketch of the introduction and development of the system which is there employed, and by which means 1,040,000 tons of coal are stored in this country and England, and several more millions of tons are annually handled.

In 1886 the strikes of the coal handlers at the docks of the Philadelphia and Reading Railroad Company, in Philadelphia, together with the large and yearly increasing amount of coal that was being shipped by vessels and cars from this port, caused action to be taken by the company to secure more economic means of handling the coal. The result was, after some experimenting, that a contract was made with the Dodge Coal Conveyor Company to erect and operate a coal storage and handling plant which should embody the endless conveyor idea as patented by Mr. James M. Dodge. Work was at once commenced in the fall of 1887, and the first coal-handling plant on the "Dodge system" was soon erected.



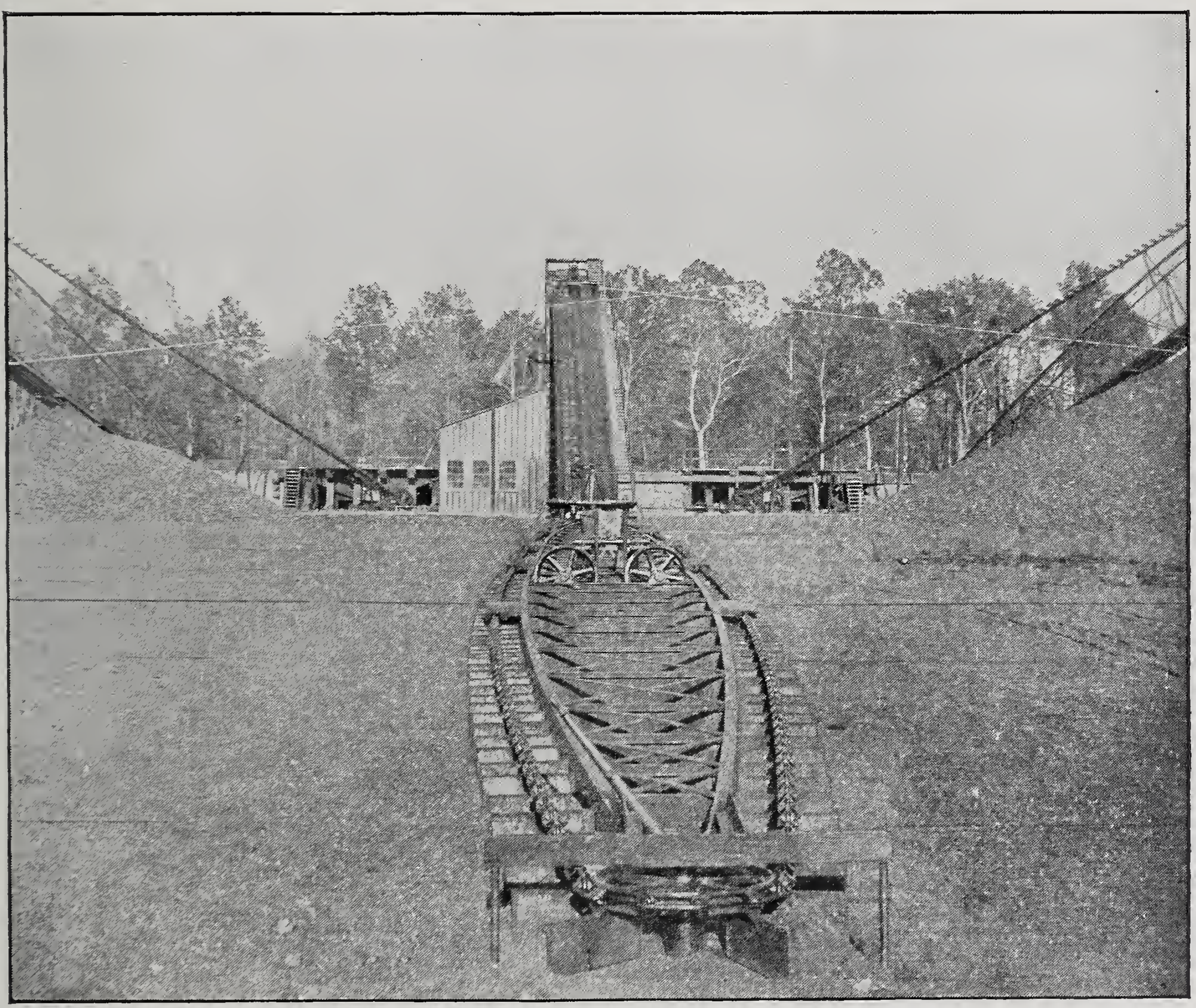
THE STORAGE PLANT, LOOKING ALONG THE TRACK.

Prior to this time the coal was dumped from the cars under trestles, and was

OPEN ACTING MECHANISM OF RELOADER AND INCLINE TO RELOADING POCKET.

trimmed by gangs of men to either side of the track, so as to admit of more coal being dumped from the same trestle. The cost of trimming coal was so great by this means that the economic limit was reached when it had been trimmed by five relays of men standing at different distances from the tracks, making the maximum cost of piling as high as 20 cents per ton. The erection of a storage plant of a capacity of 80,000 tons, having machinery for handling the coal at the rate of three tons per minute, and requiring only an engineer and five laborers, entirely dispensed with the large gangs of shovelers which had before been required, and increased the capacity of the storage ground from a maximum of 30,000 tons to nearly 100,000 tons, effecting further economies by securing the prompt release of cars, dispensing with the building of runs, and increasing the shipping facilities.

The economy and convenience of this plant was so marked that in a short time a similar one was installed at South Amboy, New Jersey, for the Pennsylvania Railroad Company, which has since been followed by others (each showing marked improvement over its predecessor) at Oneonta, and Rondout, New York, Owaker-street wharf, New York city, Hampton Junction, New Jersey, Salem, Massachusetts, South Plainfield, New Jersey, and Fulham, London, having in all a total storage capacity of 1,040,000 tons.



A RELOADER AND INCLINE CONVEYOR TO RELOADING POCKET.

The necessity of having large stocks of coal close to the large markets of New York, Philadelphia, and New England has been, by the varying conditions of trade, felt more and more from year to year by the coal-carrying and producing railroads. To meet this necessity the Lehigh Valley Railroad Company finally decided, in 1890, to erect at

South Plainfield a plant capable of quickly storing and handling 310,000 tons of coal, thereby enabling them to hold and steady a declining market.

The plant as contracted for with the Dodge Coal Storage Company, of Philadelphia, and as now erected, occupies a little over 20 acres, and consists of seven "Dodge groups," one of which has a capacity of 20,000 tons, one of 30,000 tons, two of 40,000 tons each, and three of 60,000 tons each, with the necessary machinery for handling the coal at the rate of 1680 tons per hour, a quantity which, by the by, would take under ordinary circumstances 850 families occupying good-sized houses in New York one year to consume.

The "Dodge system," by which means this coal is stored and handled, consists in piling the coal into large conical piles by continuous machinery, so that the coal is conveyed up an incline at or about the natural angle of repose of the material; the reloading of the coal by means of undercutting the piles with an endless conveyor; carrying the coal up an incline and delivering it into a loading pocket, from which it is discharged into the railroad cars. In the construction of the plant the machinery and piles are divided into groups of two, which consist of two trimming machines, one reloader, one reloading pocket, and the necessary independent driving machinery.

GENERAL VIEW OF THE PLANT FROM THE TOP OF ONE OF THE TRIMMERS.

The "trimmers" consist of an endless cable chain, which has bearing blocks inserted between the ends of each link, to which are attached at intervals scrapers for flights. This chain ascends under and returns over one of two opposing trusses or shear legs, which are placed so as to make about the same angle with the ground as the natural angle of repose of the material. The chain also passes

below and adjacent to the track, from which the coal is dumped from the cars into a chute leading on to the conveyor.

In operation, the endless chain conveyor gathers its load from beneath the tracks, scraping it up against a flat, broad steel strip or ribbon, which is carried in guides placed on the under side of the truss, and so arranged that it can be fed forward and up the leg as the pile forms. The coal being discharged over the end of the ribbon, and having only a few inches to fall, there is no appreciable breakage of the material, and the coal is allowed to assume a conical-shaped pile.

The "reloader," which is placed between two trimmers, as will be seen from the drawing, is a long, narrow, elliptical truss, pivoted at one end, and resting on concentrically curved rails, which pass under the trimmers. On the under side of the truss, and projecting therefrom, is a broad, flat strip of steel, which acts as a trough-bottom to an endless chain conveyor, which passes completely around the reloader, then up and down an incline, passing over the top of the reloading pocket, which is placed higher than and adjacent to the shipping tracks. In operation, the conveyor is put in motion, and then the reloader is swung until it undercuts one of the conical piles of coal, when the chain carries the material along the reloader up the incline, and discharges it into the loading pocket. The loading pockets have a capacity of six tons, and are arranged with two swinging chutes, so that cars standing on two tracks may be loaded at the same time.

A RELOADER AT WORK UNDERCUTTING A PILE.

Each group has an independent Kensington high-speed engine for driving the machinery of the conveyors and for swinging the reloaders, all of which has

been running smoothly from the first, and no difficulty having been experienced in operating the installation during the winter months. The cost of handing the coal has been less than the contract guarantee, which was that it should not exceed over 3 cents per ton to move the coal in either direction; since its operation, however, the average cost of moving the coal has been about 2½ cents per ton.

The great conical piles of black diamonds, rising to the height of seventy-five feet, and which are now the landmarks of South Plainfield, give to both the casual observer and the engineer an excellent object-lesson of the vastness of the coal industry, and the application of engineering science to the economic handling of this condensed power and heat.

ROPE DRIVE FOR POWER TRANSMISSION.

By Robert Grimshaw, M.E.

ALMOST all machines in use are rotary, or receive their power on a rotating shaft, and are driven by shafting ; and almost all motors give out their power from a rotating shaft. Hence it is that the problem of how to connect a rotating driving shaft with a driven shaft which is to be rotated at some special rate of speed, and with sufficient torque or twist to enable it to do the work entailed upon the machine into which it passes the power, has become one of the most common which is presented to the millwright, machinist, or engineer (using the latter in the proper sense, and not as meaning an engine-runner).

The principal method of connecting two shafts so that power may be transmitted from one to the other is by what are known to the professional mechanic or the student of mechanical science as wrapping connectors,—this including endless belts, ropes, or chains, wrapping partly around and connecting two wheels, one of which is the driver and the other the follower or driven wheel. For most cases of power transmission wrapping connectors are better than gears, because they permit of practically any desired distance between the driving and the driven mechanism ; of practically any desired velocity-ratio, whether increasing or diminishing, between them ; and of the greatest possible range of convenience in the relative position of the shafts so connected.

Where gears are used, if the shafts are parallel they must be comparatively close together, or call for very long connecting shafts having miter gears ; and if the connecting shaft is vertical, as where the motor is on the ground floor and the driven machinery in the upper story of a tall building, great weight is entailed on the lower bearing. Furthermore, there is great friction between even the best designed and made gears ; and noise and backlash are almost inseparable from this method of transmission.

Almost any system of transmission by wrapping connectors is lighter than one doing the same work under the same conditions by gearing, and this for several reasons. The speed at which gears may be safely run is limited, and where any considerable amount of power is to be carried this necessitates gears with wide faces, giving and receiving heavy twisting strains. In turn, this calls for heavy shafts to bear the weight and stand the twist and the thrust of one gear on the other.

Another advantage of wrapping connectors over gears is, that while with the former slight or even considerable changes in velocity-ratio may be made at comparatively slight expense and trouble, gears as ordinarily made are not so mated that all of a pitch will mesh together without undue friction, noise, and backlash ; and even where the proper system of laying out and making gear-teeth is carried out, any change in velocity-ratio between two shafts having a fixed distance between their centers must be made by altering both gears, whereas with a wrapping-connector system only one wheel need be changed : either the driver or the follower may be varied in diameter, leaving the other of the original working size. Again, a still further advantage possessed by wrapping connectors in the matter of variations of velocity-ratio is that very slight changes may be made, as is often desirable in proper making, by giving one of the wheels a slight lagging or wrapping, or at most a very slight turning down of the face or of the groove. With gears the ratio must be either one thing or the other ; there can be no compromise.

English millwrights clung to transmission by gears long after Americans had in great part abandoned it ; but where they have made the change they have usually

gone further than has been the case in America, and have adopted rope drive even for the heaviest work. American engineers have been plodding along with "straps" or "bands," as they call them, or "belt," as we have named them. This is not because good belts are not made in England, for their leather is exceptionally good, and their rubber belts, while perhaps not any better than rubber-goods manufacturers could make in America, are very much better than manufacturers are willing to pay for, and in consequence dealers willing to carry.

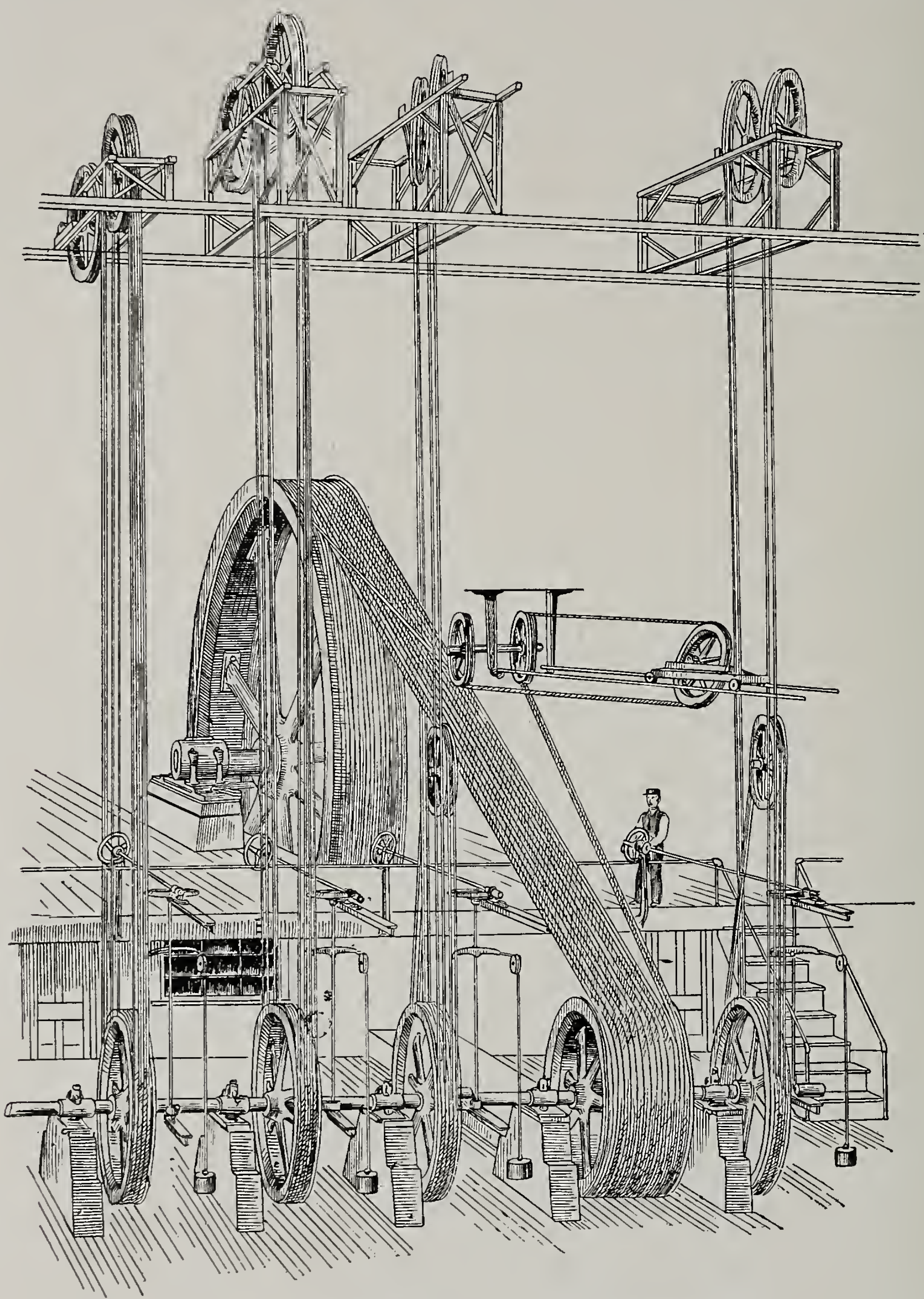


FIG. I. FLY-WHEEL OF ENGINE, SHOWING ROPE DRIVE.

Of the three principal kinds of wrapping connectors,—chains, flat belts, and rope,—each has its advantage for special applications. No one should assert that any one of these is best for all circumstances, whether he thinks so or not. Cresson, of Philadelphia, who makes nothing in his large establishment but shafting, pulleys, and the like, and who turns out driving pulleys for flat belts just the same as other people turn out spools or buttons, drives his own shafting lathes with sprocket chain, although it may be questioned if he ever sold a foot of such chain in his life, and perhaps never made a sprocket wheel. The makers of "link belts," which are de-

tachable or separable sprocket chains, use belts most liberally.

Of the three, the chain earliest meets its limitations of speed ; the belt next ; the rope seems so far to have met every successive speed increase which has been piled on it with prompt increase of duty, so what its limits are we cannot yet say.

As much less has been written about rope drive than about transmission by flat belts, and as the chain system has but limited application, it is probably desirable to devote to the rope system a special article calling attention to its advantages and disadvantages.

In rope driving "the three kingdoms"—animal, vegetable, and mineral—are drawn upon. Round-leather belting is of two kinds,—that cut in one solid piece and used for small powers, and that braided up of flat thongs and used for quite heavy transmission. Its advantages have been long known, particularly for crossed and quarter-twist belts. It gets a good grip on a grooved pulley, whether with iron or wood working surface, and has the advantage that it may be made up of scraps or refuse. The difficulty is that they are not handy to splice, except the very small sizes, which are fastened by hook-sockets, in the method familiar with sewing-machine driving bands. As against this, one familiar with rope splicing can make an admirable endless belt of braided rope, the diameter at the spliced part being not perceptibly or practically any larger than that of the portions between the joint. As, however, any leather belt, and particularly any braided one, will stretch under use, and is apt to change in length with the weather, the braided-leather cord or round-leather belt is not convenient where there are no facilities for gradually taking up the slack.

A round-leather belt is of course utterly unsuited for open-air work, or for places, as in morocco factories, etc., where the air is saturated with moisture.

Wire rope has been much used in this country for heavy transmission, particularly in the open air, as its comparatively light weight for the tension which it will stand, and its ability to keep its length unaltered by changes in the dampness of the air, make it very convenient. But no wire rope should be used for power transmission without a core of hemp or other vegetable fiber, because that construction permits its being made much more flexible than where each wire passes in rapid transition from one side to the other. The smaller the sheave over which a wire rope is used the greater the necessity for the hemp core. One bar to the extended use of wire rope is the difficulty of splicing it so that there shall not remain projecting therefrom a number of small iron or steel ends, which will rapidly destroy sheave groove lining, such as raw hide, wood, or compressed paper. The difficulties of splicing round-leather rope are greatly increased with wire ; it is harder worked, and requires greater skill and more time. The speed at which wire rope may run is limited by reason of its comparatively great weight. If a wire driving rope of considerable length once gets to "slinging" it throws on the pulleys and their shafts quite violent strains, which are liable to spring the shafting and destroy the bearings ; so as an ounce of prevention is better than a pound of cure, it is best to keep the speed down to say 600 feet per minute. The longer the span between driver and follower the greater the necessity of keeping down the speed, unless there are supporting sheaves along the line ; and these are usually good investments in any case, as they reduce the strain on the splice. As regards the size of sheaves for wire rope, we may say, in the first place, that they cannot be too large. The greater the sheave diameter the less the wire is distorted at each of the spans, and the longer it will last ; besides, large sheaves will enable comparatively slow shaft-speeds for a given rope-velocity, or putting it the other way will for a given number of shaft-rotations per minute permit higher rope-speed, and consequently less tension on the rope and on the bearings. The increased weight of the sheaves on the bearings should be given comparatively little consideration in this connection, because that is only dead weight, and a little extra bearing length will take care of that ; but strain

on the rope not only puts stress on the bearings, but tends to lessen the life of the rope itself.

Wire rope seems best adapted to transmission between parallel shafts at considerable distances and in the open air. In such cases the sheaves lie flat against the sides of the buildings between which the power is carried. They are usually overhung, but it would be better to give them outboard bearings, which can be done very readily by a yoke slightly larger than the diameter of the pulley and having an outside bearing at its center. This yoke may lie horizontal, or be in a horizontal position, according to the way in which the belt is taken up; the main purpose being to prevent the weight and sling of the rope bending the shaft outside of or in the bearing, and causing the sheave to wabble or "weave."

By reason of the sag of wire cables it is often necessary to provide them with trenches in which the belly may lie; this, of course, in case there are no intermediate pulleys to serve as bearers. Where it is not convenient or desirable to use intermediate pulleys, or to have a trench for the sag to lie in, it will be necessary to put on more tension and thus straighten up the loop; and this, of course, will call for ropes of greater diameter, which, in turn, necessitates heavier shafts and longer bearings, to stand the increased weight and the increased pull due to both the weight and the tension.

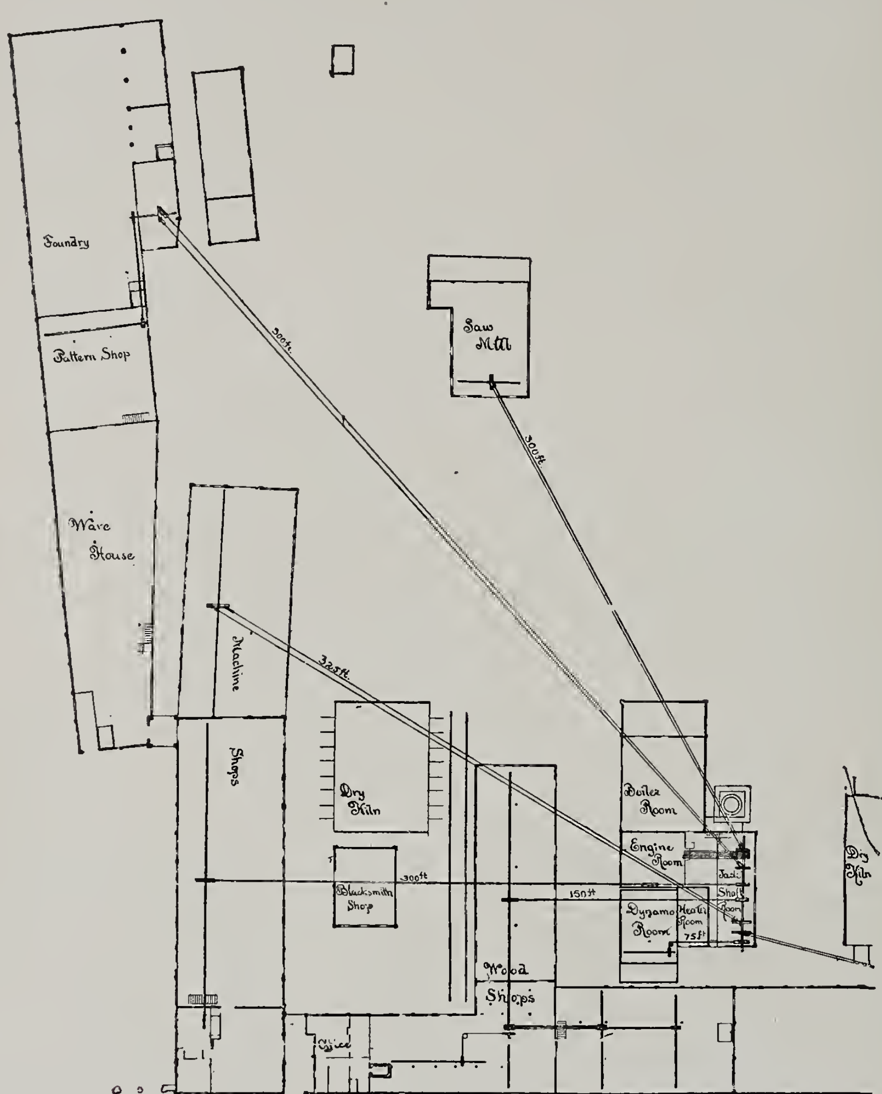


FIG. 2. ROPE TRANSMISSION AT WORKS OF DODGE MANUFACTURING COMPANY. GROUND PLAN.

Wire ropes will run well in ordinary cast-iron grooves if these are made with an angle of about 60° and have easy curves at their bottoms. There is, however, some advantage in filling the bottoms of the grooves with hard wood or with raw hide.

But the driving ropes which are doing the best service and the most service to do are cotton flax, hemp, or manilla,

each having its advantages for certain uses. The advantage of these ropes is their great lightness and cheapness,

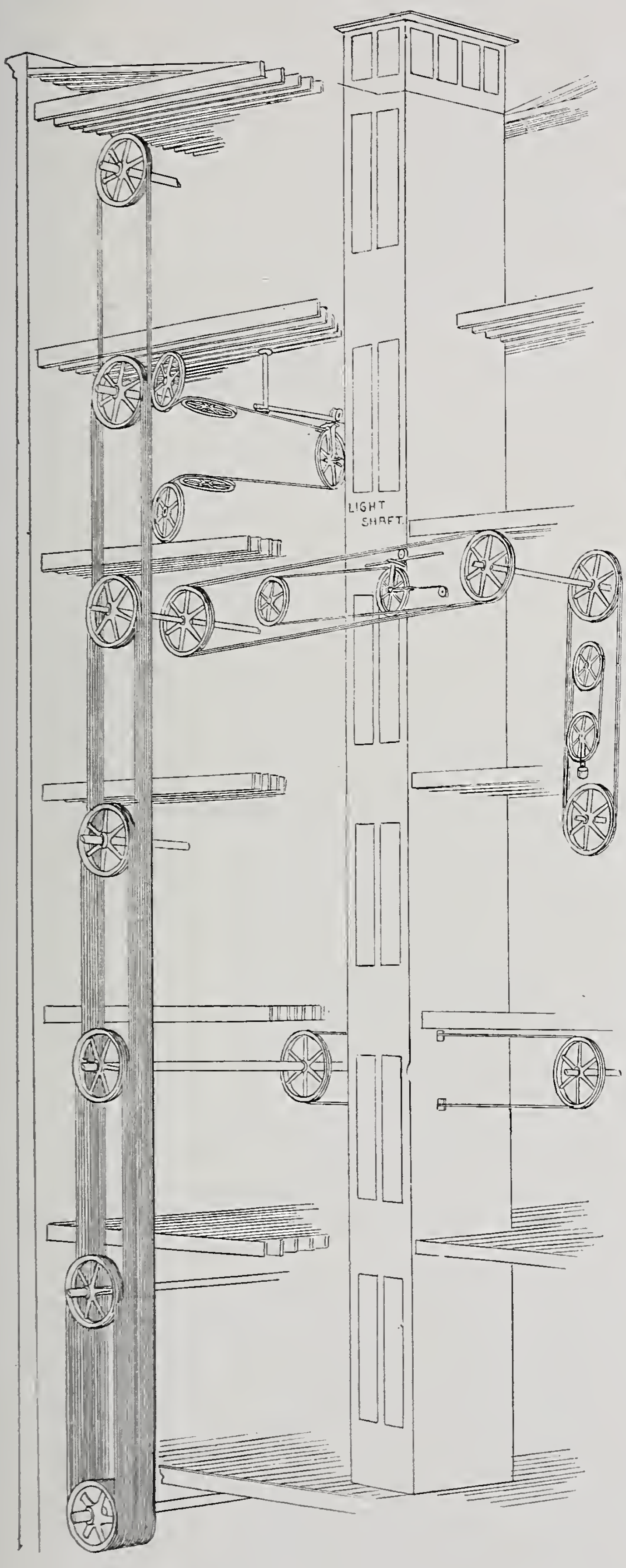


FIG. 4. PLAN FOR VERTICAL TRANSMISSION.

their extreme flexibility, the ease with which they can be purchased in any place where supplies of almost any kind can be had, and the ease with which they are spliced. Being light, they put but slight strain on the bearings for a given driving tension, and they have but slight sling when running fast; and being very flexible, they accommodate themselves very well to the most sudden changes in direction, and will also permit the use of smaller pulleys for a given rope diameter than the wire. They will run well on wooden drums, either grooved or plain, without destruction of either themselves or the pulleys; and they will also run in grooved iron sheaves or in grooves on iron drums. They are very well adapted to running, side by side, several strands in one transmission; and in this way they may be used either in the European manner, with several separate endless ropes, side by side, or in the American way, in which a single endless rope takes many wraps about both pulleys and the winder; or they may be used with a combination of such methods. If the pulley is grooved, they keep approximately their proper circular cross-section; if they have to run on flat drums, they accommodate themselves to this flat surface, and give enough contacting area to get what drive is required. Anybody, mechanic or not, can splice them. They alter considerably in length, but this can usually be taken care of either by an idler-wheel or roller, as in the English system, or by a sliding carriage, as in the American way, in which all the slack of several turns of rope may be either automatically taken up by a weight attached to the winder carriage, or regulated at will by screw and hand-wheel adjustment. But their use is not always to be recommended for out-of-door transmission.

They differ from wire ropes in that they are as well adapted for close shafts as for distant ones; and they have the advantage over flat belts in this as well as in the fact that where both shafts are horizontal, but one is directly or nearly directly over the other (as in an elevator), there is not such weight of the wrapping connector itself as to cause it to sag away from the lower surface of the under pulley,—a fruitful source of trouble where there is, say, a 48-inch belt, 200 feet long. Where an engine

in the basement has to drive a jack-shaft directly overhead and close to it, and that again to turn a line-shaft directly over it on the floor above, and either parallel or crossing it, the vegetable rope comes in with particular advantage. There is no quarter-twist or skew which it will not take just as well as where the shafts are absolutely parallel. The same rope may be used to drive a number of spindles, as in gang drills, running over and under, under and over, giving four

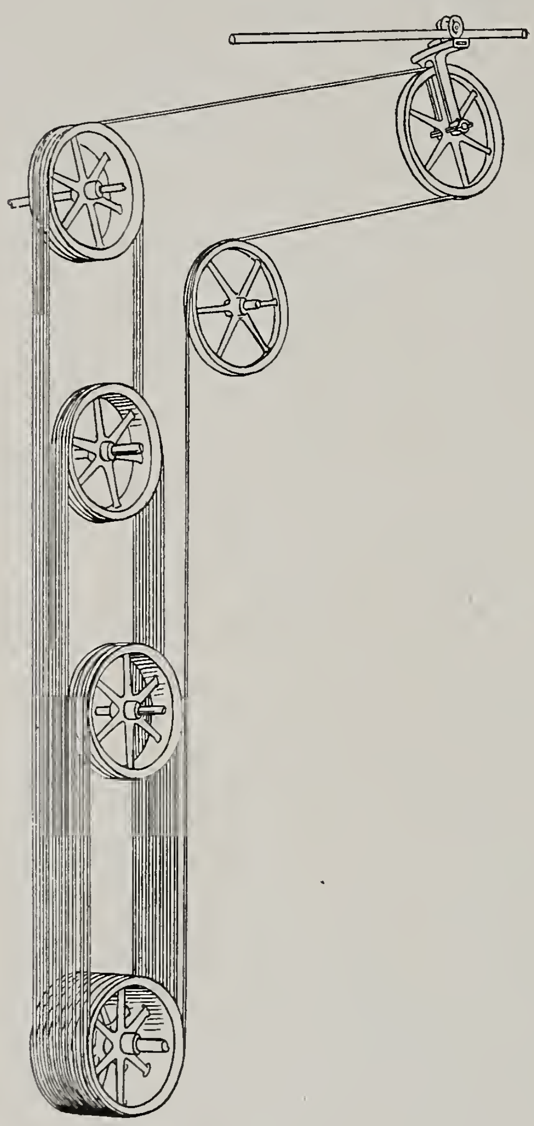


FIG. 3.

to 20 spindles the same speed or different speeds from a single drum, and enabling the drum to be run at moderate speed, and the augers to be rotated 4000 to 7000 turns per minute if desired.

As to the maximum speed, I have said that it has not been reached ; but 6000 feet per minute is very common. I should not hesitate to run soft ropes 10,000 feet per minute if I could do so without undue shaft-speed on the one hand, or excessive pulley-rim-speed on the other.

A good example of manilla rope drive is seen in Fig. 1, which is taken from the plant of an establishment which, having devised the system solely for its own use, has ended in having as a branch business one of the largest manufactories of wooden pulleys and rope-driving machinery in the world. Fig. 1 shows in the background the fly-wheel of the main engine, 22 feet in diameter, and making 75 turns per minute, the power being carried off by a manilla rope 1 inch in diameter to a jack-shaft pulley 99 inches in diameter, and making 200 turns. This rope makes 14 turns around the driving wheel, and also around the jack-shaft pulley, the slack going over one of two guide-pulleys on a horizontal axis, from which it passes to an idler-pulley or tension-pulley borne by a truck or carriage sliding on horizontal ways and drawn away from the guide-pulleys by a weight, so as to keep the rope at all times properly taut whether the load is light or heavy, and whether shortened by damp weather or lengthened by dry. The tension on the driving side with maximum power of 450 horse is about 204 pounds, its actual breaking strength being 7000.

This rope costs about 6¾ cents per foot retail, and there are 1800 feet in the rope used between these two pulleys, which, by the way, are 55 feet between centers.

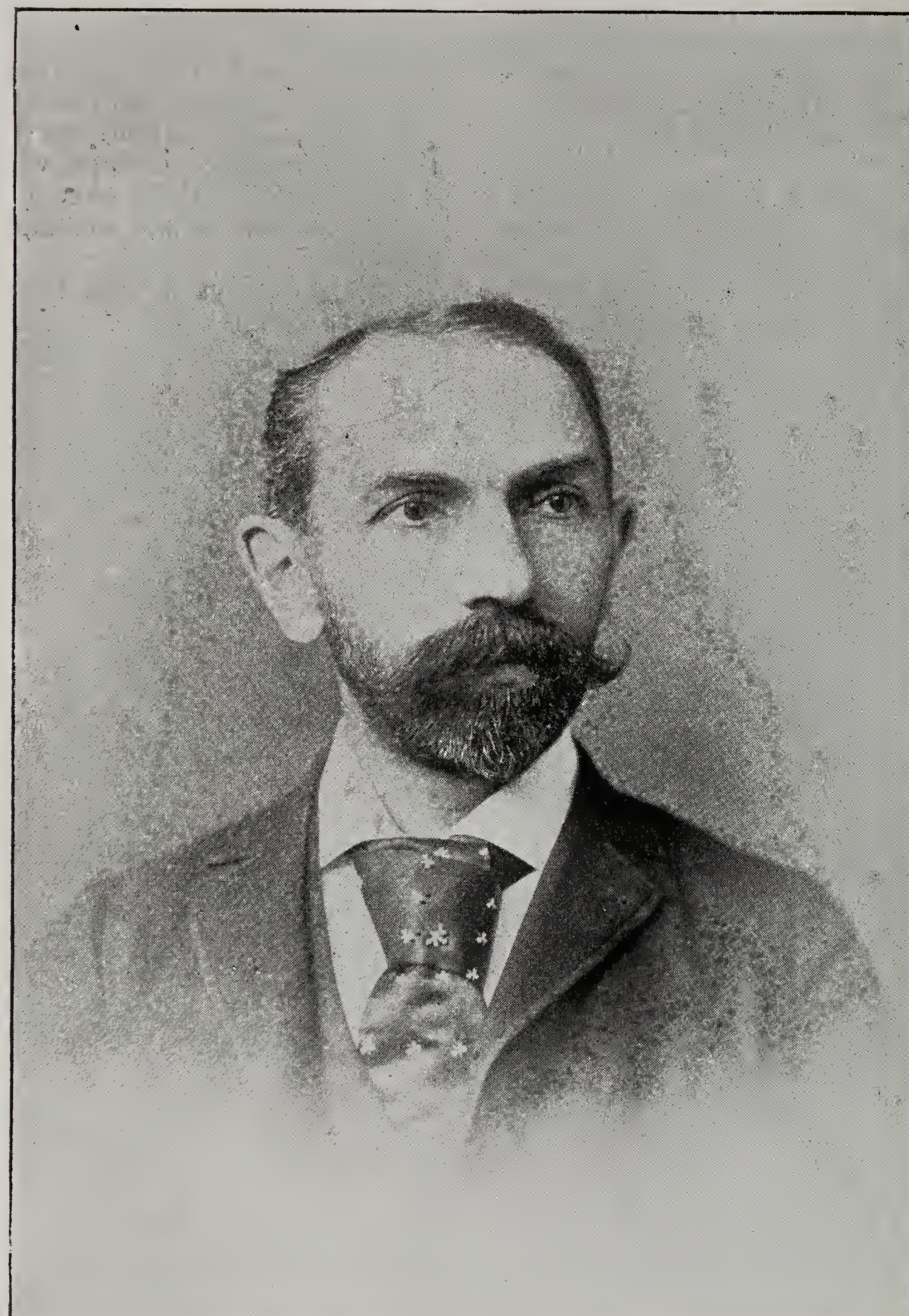
The reader can figure for himself that the speed of this rope is 5175 feet per minute. It is called upon to transmit, at this speed, as high as 450 horse-power.

On the jack-shaft there will be seen four grooved pulleys, from which ropes pass to guide-pulleys overhead, whence they go to various portions of the works, as shown in the ground plan, Fig. 2, the distances between shaft centers being, counting from the four pulleys in their order from left to right, 300, 150, 600 and 350 feet. There are also, as shown on the ground plan, other rope-lines from this jack-shaft not shown in Fig. 1. All the pulleys leading from the jack-shaft are 7 feet in diameter, and the rope-speed leading from them is 4400 feet

per minute. The four rope-lines leading from the jack-shaft (each of which is composed of one endless rope) carry respectively 75, 175, 45, and 90 horse-power to the first and second machine shops, the foundry, and the saw-mill. Besides this, there are 65 horse-power taken from two other lines, making a total of 450 horse-power, all carried to the jack-shaft by the first rope-drive system, and all carried from it by the other lines.

Fig. 3 shows a vertical transmission suitable for carrying power of several shafts on different floors from a shaft on the lower floor or in the basement, and Fig. 4 shows a similar but more extensive transmission and several secondary tranmissions impelled by the main drive. In all, the leading principle is the same, and is American : the continuous wrapping of one endless rope two or more times around the pulleys, with a single tension-pulley to take up the slack, as distinguished from the English system of having as many ropes and as many splices as there are strands employed, and without tension other than the weight of the rope, which unfits it equally for arrives except those of moderate distance and substantial horizontality.

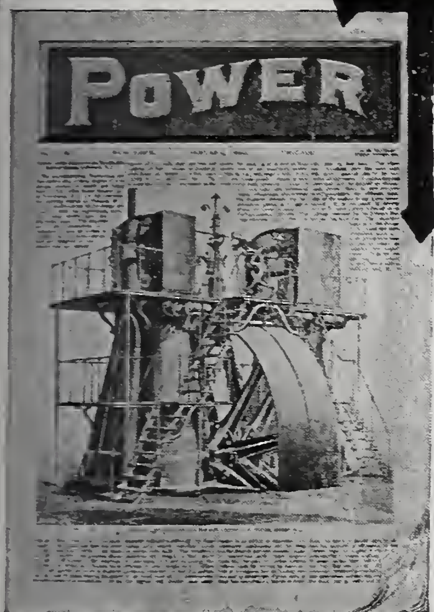
All the pulleys in Fig. 1 are of iron with V grooves.



H. M. SWETLAND.

TECHNICAL JOURNALS IN AMERICA.—I.

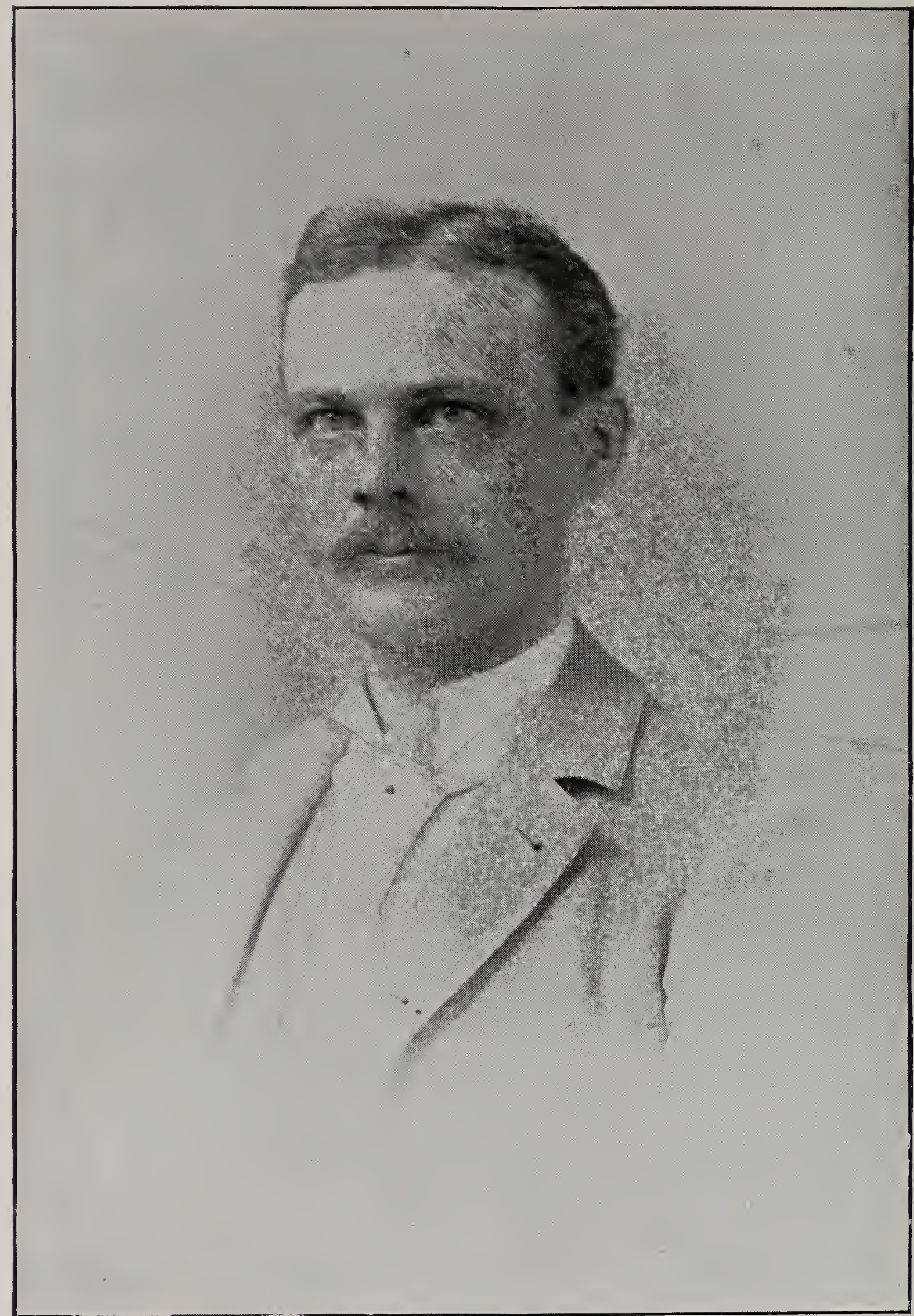
By Charles H. Werner.



THE knowledge which makes a man valuable in a trade or profession consists to a certain extent of facts directly determined from his own experience, and to a greater extent of facts and principles derived from the experience and deductions of others. Under the apprenticeship system, young men bound themselves to long terms of service, with little or no compensation, that they might obtain the benefit of the experience and methods of others in doing work for which without such aid they could perhaps have never qualified themselves. The prospective member of a profession attends a long course at an institution of learning, that he may absorb the recorded experiences and deductions of the workers and thinkers who have made the profession what it is. No one man, however varied his practice, however extensive his opportunities for experiment and observation, however acute his faculties of reasoning and deduction, can make material progress in any of the branches of applied science without availing himself of what has been worked and thought out by previous laborers in the same field. All practice is therefore based to a large extent upon precedent; and through interchange and discussion, record and study, one man's experience becomes the precedent of many, and the knowledge of each comprises the combined practice and study of all.

In these days of rapid development, when a half century is sufficient to produce our elaborate system of railroads and to divide by four the amount of coal required for the production of a given horse-power; when a decade produces such an industry as electric lighting, and when numerous processes of manufacture are born, established, and become important trades in a single generation; when thousands of active brains are at work developing processes by which the work necessary for the prosecution of these industries may be done cheaper, quicker, or better, and thousands of manufacturers and capitalists are just as alert to seize upon and apply anything which will give them a possible advantage over their competitors,—increased facilities for the interchange of thought and experience, for disseminating a knowledge of progress and processes, for placing the demand in communication with the supply, are necessary, and this need has been admirably met by the printing press through the medium of the technical journal.

The technical journal of the present day possesses enormous power for good or evil. To entirely fulfill the responsibilities of its position, and to make the best use of its possibilities, it should furnish not only a record of the progress of the industry to which it is devoted, not only the means for an interchange of opinions and results upon every mooted question pertaining to that subject, not only the means for inventors and manufacturers of appliances and wares pertaining to its processes to reach their customers, and to the customers a means of knowing where and how to procure the latest and best appliances which have been developed for their use, but it should be a director of progress by pointing out lines of possible development and urging the fallacy of ill-directed efforts. It should have opinions of its own, derived from an intelligent understanding of the subject and its conditions, and expressed without fear or favor. Its ultimate establishment as



F. R. LOW.

an authority to be relied upon and respected depends upon the ability of its editors to decide correctly and the courage of its publishers to express its editorial convictions without restraint by considerations of patronage. It should not only present its readers with the earliest information of new appliances .and processes designed for their use, but should be qualified to judge of their desirability, and should criticise fairly whatever may be open to criticism rather than commend indiscriminately with a view of pleasing a present or possible patron. It should be a general bureau of information upon the details of its industry, and the first source to which one of its constituents would naturally turn for advice and direction upon matters relating to his plant or his work. Such a paper, once established, cannot well be spared by the industry which it represents, nor by those who are catering to that industry.

Some eight years since, Mr. H. M. Swetland and others saw in the generation and transmission of power an inviting field for a technical journal. The army of proprietors, managers, superintendents, master mechanics, and engineers in charge of power-producing and using plants promised to furnish an extensive, intelligent, and valuable *clientele.* The importance of economy in the production and use of power in industries where power is an important factor, the fact that the average plant is capable of improvement in design or operation or both, and that the owners and operators are interested from the strongest motives to know how this can be done, the continued progress in steam engineering and its growing application to new industries, appeared to warrant the conclusion that a paper which should treat of the principles of sound practice, describe in detail successful model plants, tell what to do and how best to do it in order that required results shall be produced with the least expenditure from all causes in the power department, would meet with a favorable reception, and that an extensive circulation among the power-using public in all trades and industries would render its advertising columns of value to the manufacturers of steam and power appliances, who were then obliged

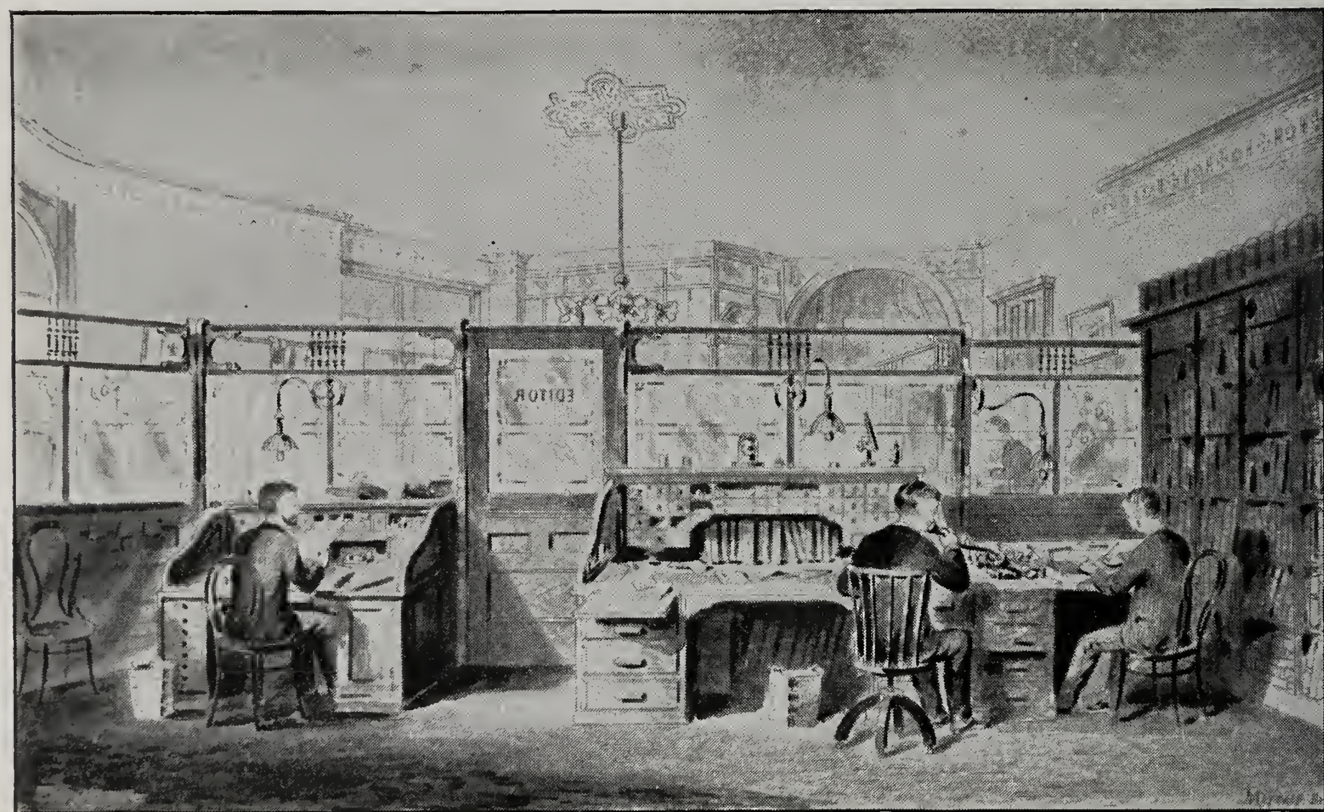
GENERAL MANAGER'S OFFICE.

to reach the mechanical man in the different trades by advertising in the special journals of all.

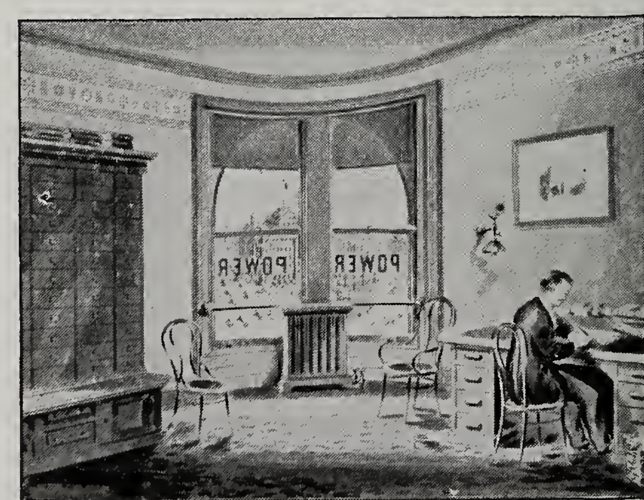
With this cause for its existence, the first issue of *Power* came from the press in November, 1884; and the journal *Steam*, then in its fifth volume, having been purchased by the projectors, this word was incorporated into the title of the new paper, which thus became *Power:—Steam*, by which name it was known until the beginning of the present year, when the word *Steam* was dispensed with, and the title became, as originally intended, simply *Power*.

The first issue was 12 pages in size, and the edition printed was 5000 copies. The salutatory contained the following announcement, which has been a guiding principle in the later conduct of the paper: "The sole disposal of editorial work and expression rests with the editors and with them alone, and any expectation of editorial notice not based on the editor's favorable knowledge of the matter in question will not be fulfilled."

So well was the paper received that the second issue was increased to 16 pages, and the end of its second year of existence found it double its original size, with a paid subscription list of over 12,000. The history of the paper since that time has been one of steady growth and development. Only one important change of policy has been made, and that in the subscription department, when it was decided to obviate the dissatisfaction and misunderstanding unavoidable under any other system by limiting the subscription list strictly to those who had paid in advance. The importance of this decision may be realized when it is said that it meant the cutting off in a single month of be-



EDITOR'S ROOM.



tween 6000 and 7000 names, a number exceeding the entire circulation of many trade journals; but the publishers had judged wisely, and within a few months the paid-in-advance list exceeded the former total edition. This policy has since been rigorously adhered to, with the result that the present constituency is a live and interested one. The paper at present is from 56 to 64 pages in size, and the edition numbers 20,000 copies.

Power was originally published by the American Railway Publishing Company, and upon the dissolution of that company passed into the possession of Mr. H. M. Swetland in 1888. In order to permanently interest his associates in the business, he organized in 1890 the *Power* Publishing Company, with the following officials: H. M. Swetland, president and manager; S. W. Hume, vice-president; F. R. Low, secretary; A. B. Swetland, treasurer.

The offices of this company are upon the eighth floor of the new building of the New York *World*, and a general idea of their arrangement and appearance is conveyed by the accompanying illustrations. The offices are equipped with every facility for rapid and accurate work, including a complete equipment of phonographs, an extensive library, a well-kept file of engineering information, files of all the machinery appliances and accessories in use about a power plant; and these means for furnishing prompt and reliable information are utilized to such an extent that the office has become a national headquarters for those interested in this field of engineering.

BUSINESS OFFICE.

Mr. H. M. Swetland, the president and general manager of the company, was born in 1853 in Erie county, Pa., and the first ten years of his business life were spent in teaching. His first connection with technical journalism was in 1880, as western representative of the Boston *Journal of Commerce*, and his experience in that field led to the conception of the ideas on which *Power* is based. In 1884 he assumed, with the American

Railway Publishing Company, the position of eastern manager of *Power*, and within a year was intrusted with the general management of the paper. This management he has continuously retained, and the success of the paper is a substantial evidence of his ability as a live and energetic publisher.

Mr. F. R. Low, the present editor, was born in Chelsea, Mass., in 1860. He began his business life in a telegraph office, taking advantage of the "let ups" to perfect himself in stenography; and after a term of service as reporter about the courts and press of Boston, he became associated with the Boston *Journal of Commerce* in 1879. With a natural taste for mechanics, which earlier opportunities had enabled him to cultivate, he found in the steam-engineering features of that paper a congenial field of effort, and upon retirement of the editor was placed in charge of that department. In this position his duties comprised, besides the preparation of matter for the paper, the performaace of expert steam-engineering work among the mills. This experience particularly fitted him as a technical writer, and in 1888 he was offered and accepted the position of editor of *Power*. He is an associate member of the American Society of Mechanical Engineers, deputy-president for the United States of the National Association of Stationary Engineers, and an active and honorary member of many of their associations; and his intimate connection and extensive personal acquaintance with his readers has enabled him not only to judge of their requirements, but to exercise that faculty of presenting abstruse matters in an interesting and understandable way which has so largely contributed to the favorable reception of the paper.

AN EXPERIMENT WITH ALUMINUM.*

By W. Wallace Christie.

ABOUT two years ago the writer was detailed by Mr. F. W. Snow, superintendent of the Ramapo Iron Works, to make a series of mixtures for cast metal and to test the castings, and this paper is prepared with the hope that it will be worth preservation with the numerous tests of aluminum compounds already recorded.

Mixture No. 1:

Wrought-iron turnings	10	pounds.
Cast-iron turnings	10	"
Steel-rail chips	10	"
Ferro-silicate of iron and aluminum	2	"

Test No. 2:

Wrought-iron turnings	10	"
Cast-iron turnings	5	"
Steel-rail chips	15	"
Ferro-silicate of iron and aluminum	2	"

The melting was done by a well-known brass-founding firm in their brass furnace. In order to melt the mixtures very high temperature was required on account of the wrought-iron, which requires 3000°; so the crucible was covered with a carbon-lid and coal heaped upon it. Even then about three hours' time was required to melt it, and after being melted the ferro-silicate of iron and aluminum, which had been left out, was added, and thoroughly stirred through. The castings made were 1½ inches diameter by 14 inches long, and in green sand without any charcoal facing, and after the skin of sand had been removed from the castings they were very smooth and clean.

Mixture No. 1 was very fluid when hot and white, but had to be poured quickly, as it soon cooled.

Mixture No. 2 was not as fluid nor as white as No. 1.

Mixture No. 1 made a very homogeneous casting; No. 2 not nearly so

* From a paper read before the American Society of Mechanical Engineers.

much so, and its fracture duller than No. 1, which latter was very bright.

It may also be said that pieces of both mixtures which have been on my desk since April, 1890, when they were cast, have retained their original brightness, which speaks well for the small percentage of aluminum in them.

Mixture No. 1 could not be touched by a specially tempered cold-chisel, but its edge was entirely destroyed. The piece of mixture No. 2 shows where a toolmaker had used an hour's time cutting off but little, and during that time the tool required many sharpenings ; I believe, five or six. When heated to a high red heat they both crumble when struck with a hammer, but when heated to a dull red heat No. 1 was placed under a steam hammer, and though quite resisting, allowed itself to be flattened to about 1¼ inches thick before crumbling, but gave better results when annealed over one night.

No. 2, when heated in the forge to a dull red heat could be flattened to about ¾ inch thick.

Having in his possession a piece of No. 1 when doing some laboratory work at Cornell University, the writer had it remelted and cast into the usual shape for tension tests. This piece, though but 8½ inches long, was put in a Fairbanks testing machine, but as it was uncertain as to just how it would act no extensometer was used for fear of the test-piece breaking suddenly. Breaking occurred at a scale reading of 13,860 lbs. The piece broke, however, in the jaws of the machine, and in the larger section of the piece, as there was a flaw in it (cinder flaw). For fear of breaking the jaws of the machine the test ended here. After breaking the smaller section in the impact machine, the area was obtained by a planimeter as .31 square inch, which makes the tensile strength per square inch at the time of breaking 44,710 lbs. This would have been higher, and probably considerably, but for the flaw and untrue grip of the jaws, which caused a combined transverse and torsional strain.

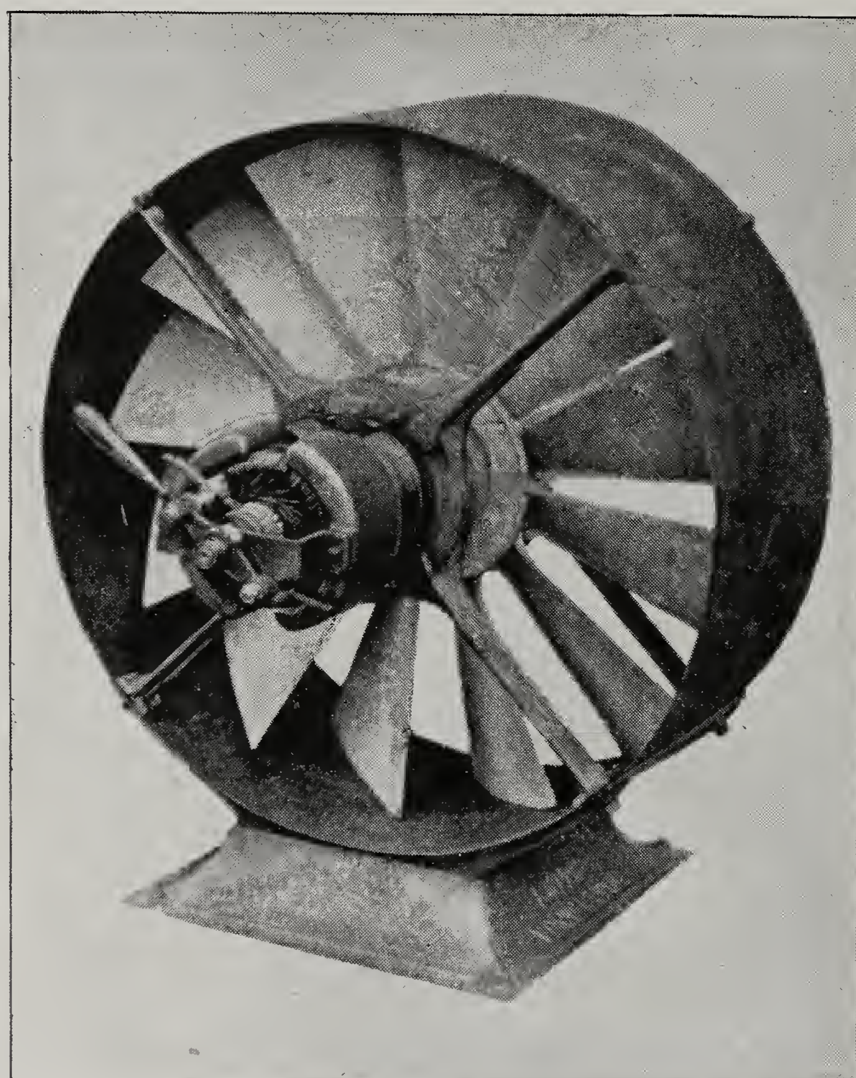
The area of smaller section was less than that of the sound portion of larger section, hence its use. When placed on a Heisler impact machine, between supports, 6 inches apart, a weight of 25 lbs. falling 1¾ inches was required to break a circular section of .31 square inch. Two uses for this metal have suggested themselves to me : one for floor-plates in a boiler- or engine-room where great strength is not required, but where wear is. Also as bearings for pivots. Of course, it is not desirable to use it for work requiring finishing, as it is too hard for that, except when done on a grindstone. The ferro-silicate of iron and aluminum used was an ordinary commercial article, purchased in the open market, and whose composition the writer was unable to learn.

No. 1 is much harder to grind than No. 2, and both present very smooth surfaces, as can be seen by the inspection of the specimens.

NEW ELECTRICAL VENTILATING FAN.

THE accompanying engraving shows a ventilating fan driven by an electric motor, which the Huyett & Smith Manufacturing Company, of Detroit, Mich., have recently placed upon the market. An examination of the cut will make the operation of the fan tolerably clear. The motor is carried by the frame so attached to the driven fan that it brings the air gap between pole pieces at right angles from framework of driven fan, thus avoiding all magnetic leaks. (In the ordinary type of motor the fan blades short circuit the magnets, thus wasting useful power, and causing sparking.) These motors are sparkless at their point of commutation and run noiselessly.

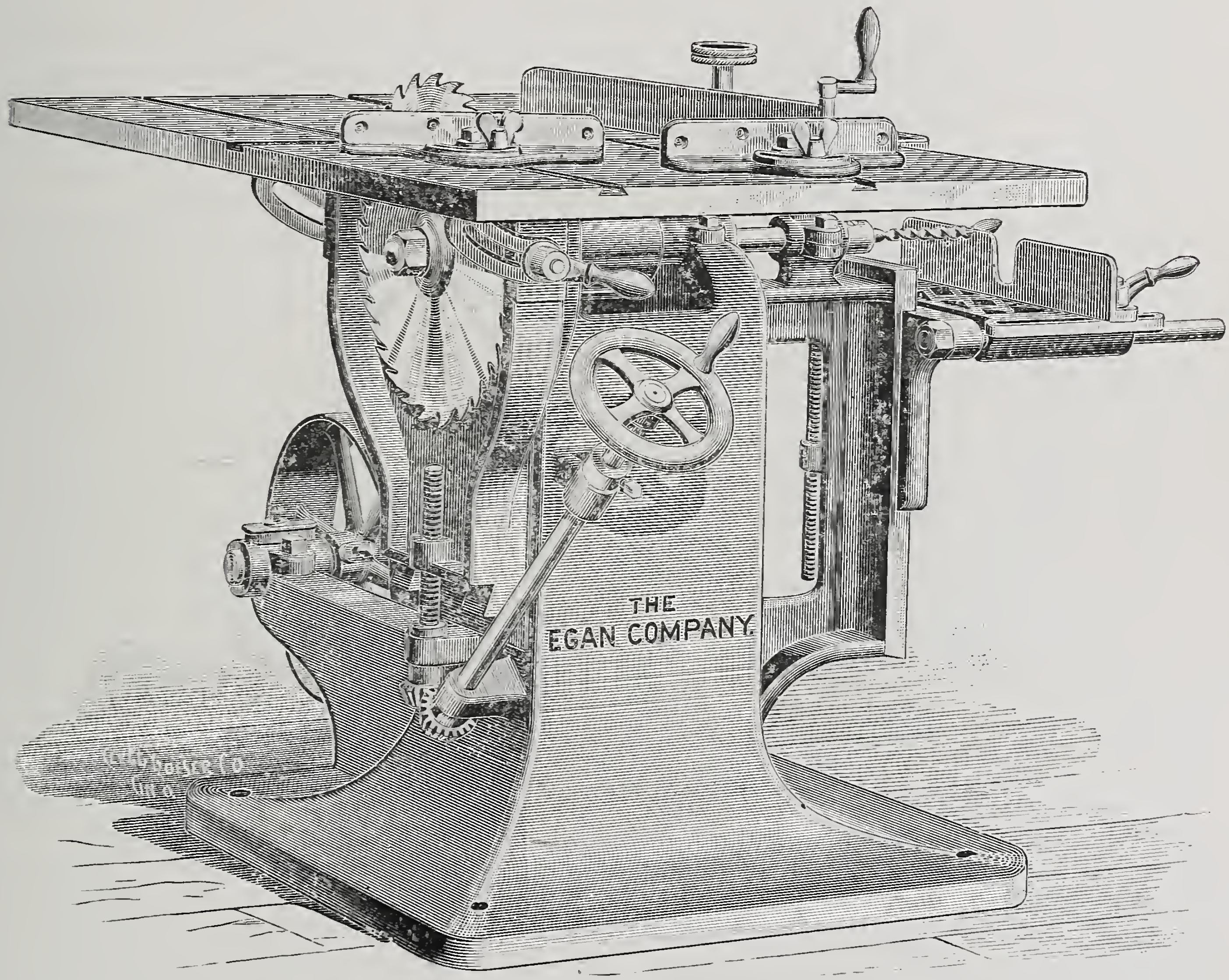
The windings of these motors are such that no rheostats or external resistance is required to run them different speeds. A simple switch on the motor will control the amount of air handled by the fan by increasing or decreasing its velocity. In other words, by a slight movement of the switch we get a June, July, or August breeze, on cool days slow speed and hot days high speed. This attachment has been patented by R. Fuller, and is manufactured by the Fontaine Crossing Company for the Huyett & Smith Manufacturing Company, ventilating engineers, Detroit, Mich.



The extreme simplicity of this arrangement, the fact that there is really but one moving part, and that the mechanism is complete in all details as it stands, combine to make the arrangement one having decided advantages. The fans can be placed in any desired position, and they are kept in stock in all sizes, capable of furnishing from 6000 to 40,000 cubic feet of air per minute.

IMPROVED VARIETY SAW.

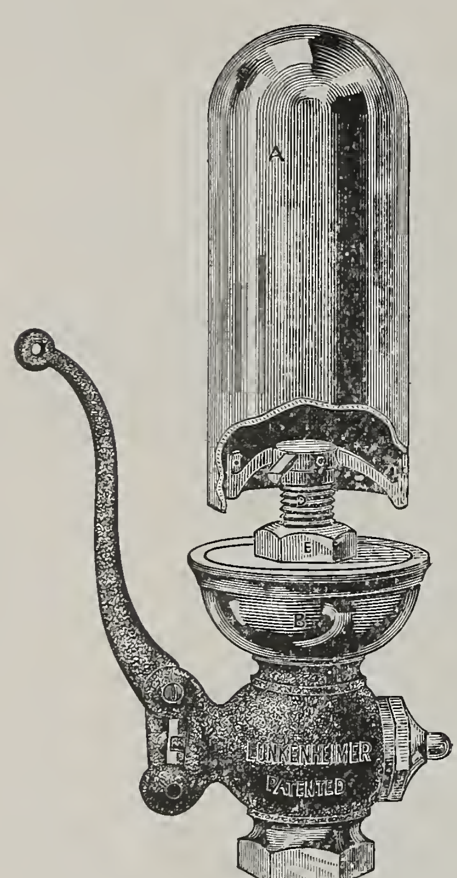
On the this page is published an illustration of a new variety saw, which has all the advantages and conveniences of the builders' No. 1 variety saw, in the way of ripping, cross-cutting, grooving, and has the tilting table. In addition, this new saw has a boring attachment, making a very convenient and desirable machine for general work in almost any kind of a wood-working factory. The column is cast hollow, in one solid piece, with ample floor space. The extension arms for the support of the counter shaft are a part of the main frame, and extend sufficiently to give ample length of belt to drive the mandrel. The table is planed and grooved perfectly true to work straight or on a level, also to adjust up and down, and fitted with two miter guides and one ripping fence. The boring attachment is connected to the column, and has a table to raise and lower independent of the main table, so that two men can work at the machine at the same time, without one interfering in any way with the other. One end of the saw mandrel is bored out to receive the chuck or boring bit, and the other end is arranged to carry a saw or grooving head.



The builders of this machine are the Egan Co. of Cincinnati.

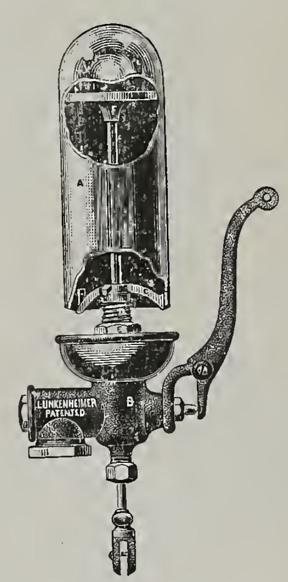
A NOVELTY IN STEAM WHISTLES.

THE illustrations herewith show a new improvement in steam whistles. As will be seen, the central stem is done away with, and instead of the usual square top with acorn, it is dome-shaped. The bell or dome is securely



fastened at its lower end to a three-armed prong or spider, the stem of which is threaded to admit of being screwed into the base and there held secure by a jam-nut. Owing to this construction the lower edge of the bell is always exactly in line with the slot in the case through which the steam escapes, insuring best results and a perfect, clear and loud tone. The bell can be raised and lowered to suit the steam pressure by screwing it up or down, and when properly set is fastened by the jam-nut. It has been proved by practical tests that she prongs to which the bell is fastened do not in any way interfere with the volume or quality of the sound.

This whistle may be changed to a fire-alarm whistle without delay by a valve which is already attached. It is provided with a piston that can be moved up or down within the bell or tube, thus changing the interior length of same and consequently also the sound of the whistle. When the piston is not operated the whistle gives but one sound like any ordinary one, but when pulled up or down a series of howling, penetrating sounds is produced. When placed above the roof



of a building an extension rod must be attached to the piston and a rope or wire to the whistle-valve lever.

These whistles are manufactured by the Lunkenheimer Brass Manufacturing Company, of Cincinnati, Ohio.

Reflections and Observations.

A FEW years ago a manufacturer from Providence obtained an order for an engine to go to Cheyenne, Wyoming, where the "rustlers" and the ranch owners have been exterminating each other recently.

Cheyenne has a delightful climate when the wind doesn't blow; but it blows nearly all the time. It is a very good place for game, and the tables of residents usually are burdened by various kinds of wild flesh.

The engineer who went up to Cheyenne to set up the engine just mentioned got there during one of the windy periods, and for a day or two was very much pleased with the weather and the barren look of the place.

The freight train on which the engine was to arrive got off the track before it reached the windy city, and my friend was thoroughly disgusted with his prolonged stay.

About the end of the second week he was at dinner, and a dish whose origin he did not know was passed to him.

"What is that?" he asked. "Why, that's prairie hen," replied the waiter.

"Well, what does it look like when it's alive?"

"Oh, it has wings and two legs, and looks something like a hen."

"You say it has wings?"

"Yes, of course; but it doesn't often fly. It can walk along pretty fast, though."

"Well, take away the dish. I don't want any of it. Anything that has wings and won't fly away from this barren old town isn't fit to eat."

MR. PARK BENJAMIN, the editor of the new edition of "Appleton's Encyclopedia of Applied Mechanics," in a recent interview said: "A great deal has been written about the nickel-in-the-slot machine as an ancient invention, and several pictures have been published purporting to represent the old apparatus. I have never seen a correct one yet. Here is the old Venetian copy of 'Hero of Alexandria,' dated 1558, from one page of which I have had the accompanying fac-simile photographed. There is the actual machine and, curiously enough, it operates not by five cents, but by five drachmas. The coins strike a lever, open a valve and let out a little holy water. When they fall off the lever the valve shuts. The coins are received in the vase.

"Hero went further than that, however, and invented an automatic bartender on the nickel-in-the-slot principle, which is illustrated in the same book. This was a vase in which he put three kinds of liquor, and arranged his faucet so as to be open part of the way by one coin, still further yet by a larger or heavier coin, and then still further by a still larger or heavier coin. The text to which the faucet opened determined which chamber should communicate with it, and hence what kind of liquor should be allowed to escape. I believe this idea has not yet been reinvented at the present time."

Members of the American Society of Mechanical Engineers and others who attend conventions know that at times it is a little bothersome to call upon the "joint agent" of the various lines, who must stamp their return coupons, or they would not be accepted on the train.

Whenever there is a convention of any size the railroads make a special rate, which is open to all, and many traveling men avail themselves of the cheap rate. The ticket "scalpers" buy the return portions of tickets at fair prices, and sell them to whoever comes

along. The purchaser, as a rule, has no difficulty in getting the official stamp put upon his ticket. Once in a while they strike a snag, however. One of the drummers for a Chicago importing house bought a ticket which had been issued for a convention of the Christian Endeavor Society. The Observer does not know his name, but he may have been a relative of "Sam'l of Posen."

He took the ticket to the railroad agent and said :

"Vill you blease sign dis dicket?"

"Did you come with this convention?" he was asked.

"Vell, I should shmile."

"Are you a member of the Christian Endeavor Society?"

"Yes."

"Well," replied the ticket agent, "I don't know about this."

The man with the ticket was getting nervous, and the sweat was pouring down his cheeks.

The agent was not convinced yet.

"Do you believe," he asked, "in the Christian religion?"

The train was just ready to start, and he moved about as though upon a hot griddle as he replied :

"Vell, I don't know. But I vill belief in anyding ant anypody who vill sign dis dicket."

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SALESMEN of engineers' supplies are known to be wonderful talkers, far surpassing advertising agents, whose ability to stretch the "truf" is well known. But according to the rumors now floating about the salesmen who are converting brewers to the advantages of manufactured ice can surpass every known variety of the drummer, and not long ago one of them made a sale by proving to the satisfaction of the intended purchaser that his machine made good, smooth, easy running cold, while his competitor's machine produced hard, rough, and coarse cold.

Well, a number of drummers were sitting around the veranda of a hotel in Boston the other day when the subject fell upon the proper method of sleeping.

One of them said, "Boys, I always lie on my right side, and I never wake up till morning."

"Boys, I don't see how you can lie on your right side," said another.

"I can't sleep a wink unless I lie on my left side," said a third.

Sitting over at one side was a gray-bearded and bronzed man who looked like a doctor. He had not said a word so far, and the discussion was getting warm whether it was dangerous to lie on the left side, so he was appealed to for a final decision.

"I will leave it to you," said the man who slept on his left side.

"Well, gentlemen," replied the "doctor" "I don't know. It makes no difference to me how I lie. I sell ice machines."

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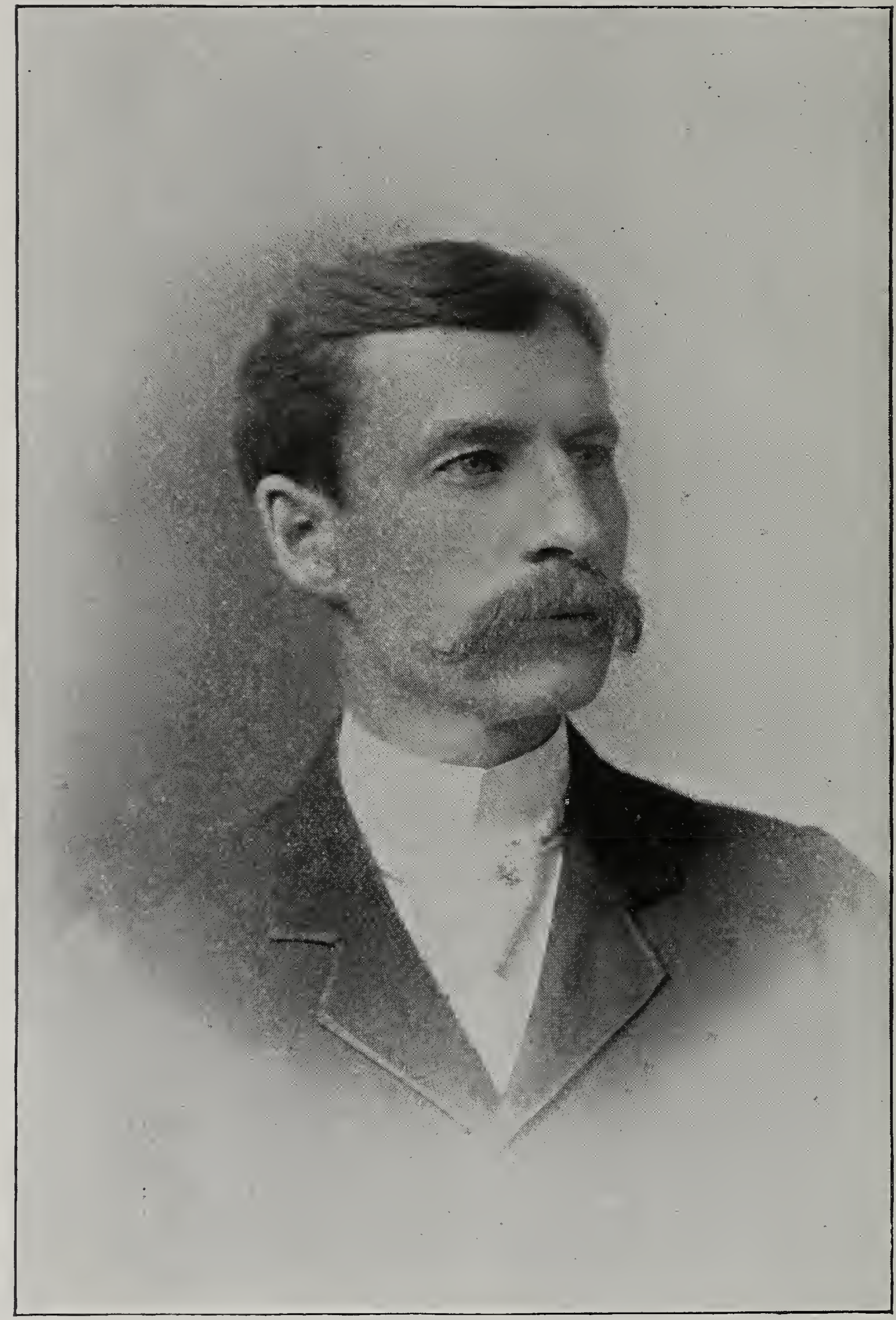
PROFESSOR Elihu Thomson in a recent article takes the view that telephoning for several thousand miles through cables will be impracticable.

"The telephone, even when first brought out, was a marvel of simplicity and effectiveness," says Professor Thomson. "When we consider that by its means we may converse with and even recognize the voice of a person distant from us a considerable fraction of the earth's circumference, we cannot fail to be impressed with the wonder of it. Can we, however, anticipate such an extension of the power of the telephone that we may at some time use an ocean cable as the line over which speech is to be conveyed? To answer this question in the negative would be to set a limit to the capacity of the human intellect to make future advances ; nevertheless, there are reasons which are cogent enough tending to point to the impracticability of telephonic transmission through cables of great length. In such cases a retardation and an obliteration of the delicate pulses of current which characterize electrical speech serve to prevent the reception of speech at the far end of the line."

THE OBSERVER.



FRANK J. SPRAGUE.

CASSIER'S MAGAZINE.

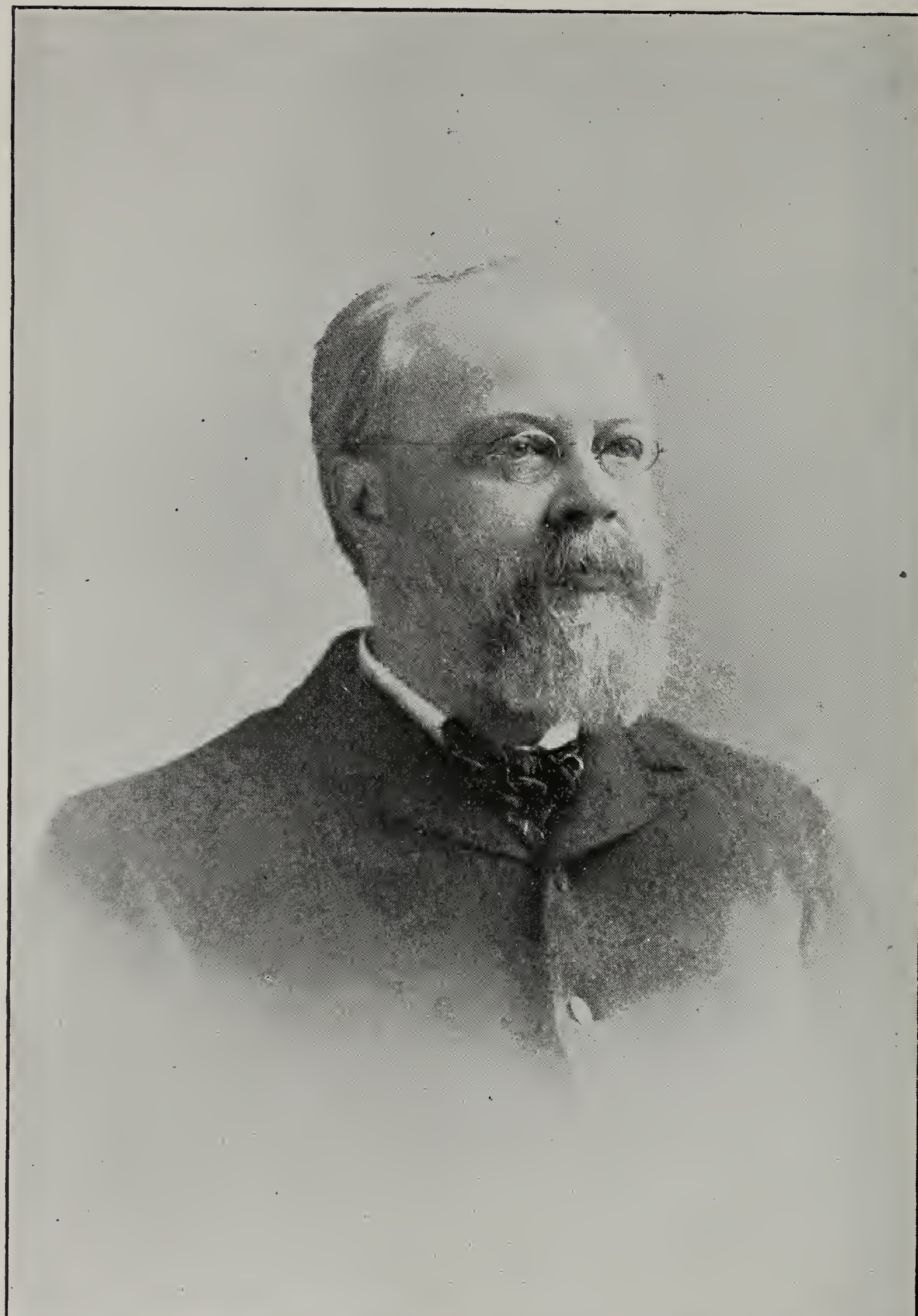
VOL. II. AUGUST, 1892. No. 10.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

THE American Institute of Electrical Engineers, the national technical society of the various branches of electricity, was organized in April, 1884, as the result of a movement started by Mr. N. S. Keith, in New York city. It was rather strange that no step of the kind had been taken before, in view of the rapid development of the electrical engineering profession; but the necessity for the existence of such a body was strongly emphasized by the calling that year of an international electrical conference in Philadelphia, and by the holding in the same city of an electrical exhibition. These two events were expected to lead to a large influx of foreign electrical engineers, and it was naturally deemed desirable that a society should be ready to welcome them and to watch over professional interests then and thereafter. The circular setting forth these ideas and other reasons for the movement was at once signed by a large number of electricians, inventors, and others, among whom may be named the late President Barnard, of Columbia College; and under the hospitable roof of the American Society of Civil Engineers a preliminary organization was effected on April 15. A month later, May 13, the pioneer work was completed by the election of Dr. Norvin Green, the president of the Western Union Telegraph Company, as president, together with such men on the council as Prof. Alexander Graham Bell, Charles F. Brush, Thomas A. Edison, Franklin L. Pope, Prof. Elisha Gray, Prof. E. J. Houston, Prof. Charles R. Cross, Edward Weston, Francis W. Jones, Prof. William P. Trowbridge, and George B. Prescott. The office of secretary was filled by Mr. N. S. Keith, and the Institute was ready to fulfill its mission. During the summer of 1884 members were enrolled, and in the fall a meeting was held at the Philadelphia electrical exhibition, at which several interesting papers were read.

Then, as usual, came a relapse, to which the natural weariness and exhaustion after the conference and exhibition contributed not a little. Mr. Keith was called to the Pacific coast, and Mr. T. C. Martin volunteered to fill his position temporarily, but was soon compelled to relinquish it under the pressure of journalistic duties.

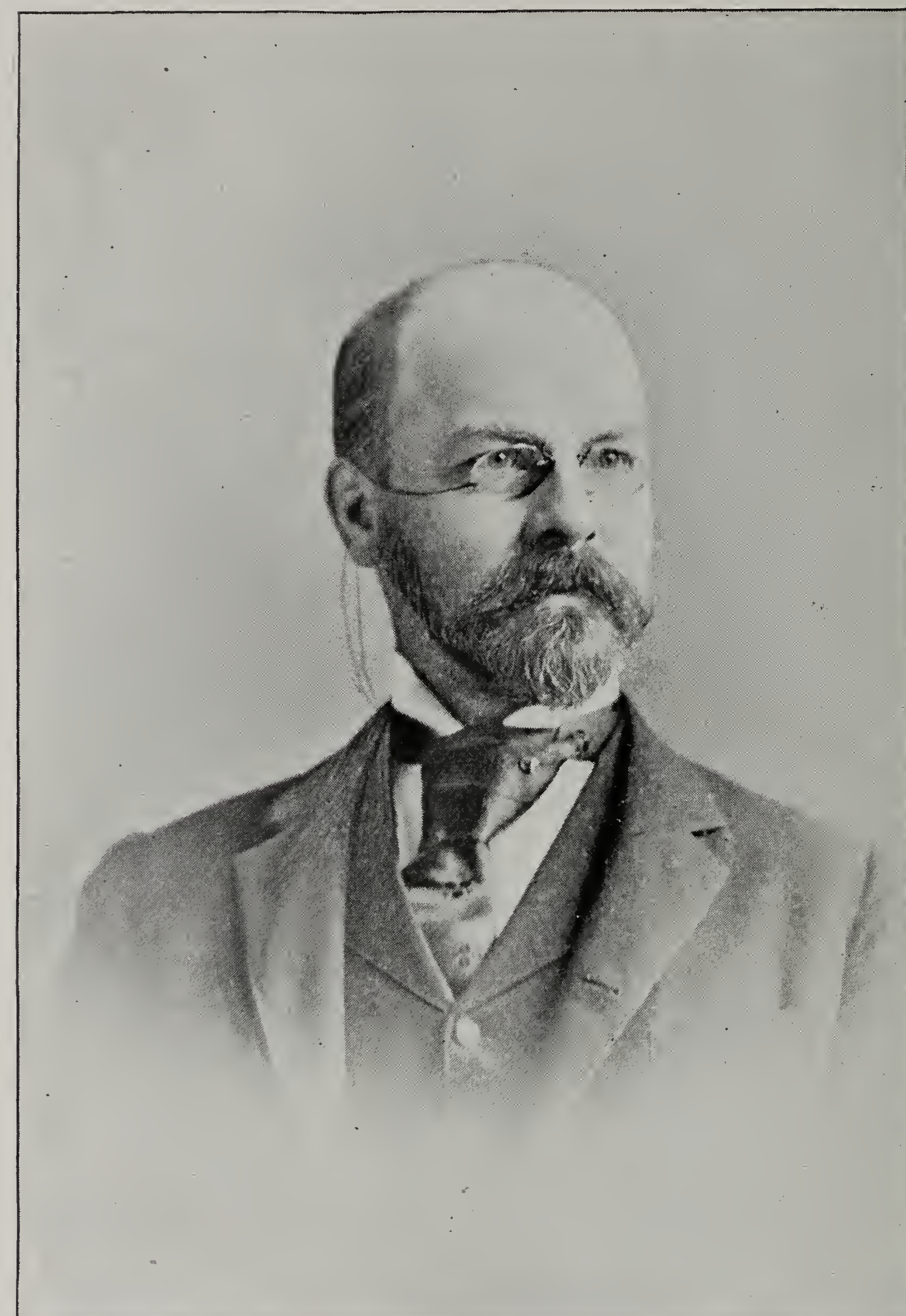
At the end of the first year the annual meeting of the Institute for the election of officers took place at the house of the American Society of Civil Engineers. Dr. Norvin Green was re-elected president, Col. R. R. Hazard treasurer, and Ralph W. Pope secretary. Mr. Pope was at that time associate editor of the monthly *Electrician and Electrical Engineer*, and had but just before been elected to associate membership in the Institute. Although experienced in the workings of associations of a different character, he was not conversant with the affairs of the Institute. He



FRANKLIN L. POPE.

soon found that there was a lack of appreciation of the work which the Institute was expected to perform; that many who had joined evidently supposed that the Institute was founded simply for social purposes. The first flush of early enthusiasm had passed away, and there was a prevailing disposition to speak slightingly of the Institute, and to inquire of those who were supposed to be responsible for its management as to the use of it and what return they could hope for from the $10 they annually invested. With such a state of affairs the officers were disheartened, for without the support of brain even money was of little use. Affairs were really not as hopeless as they seemed. There were plenty of active, able men who felt the necessity of such an organization, but they had not yet been brought to the front. It became evident that there must be a change in policy, and this was gradually brought about. The annual meetings had been carefully watched, and certain men were selected for office not because of their reputation, but on account of the zeal they manifested in the welfare of the Institute. By the rules three of the six vice-presidents and four of the twelve managers went out each year, so that no sudden change could be brought about; but a start was made, and at the annual meeting, May, 1886, Mr. Franklin L. Pope was elected president, and among the new vice-presidents were Messrs. Thomas D. Lockwood and George C. Maynard. Among the managers elected were the late Major Otho E. Michaelis, the late Sidney F. Shelbourne, and Mr. C. O. Mailloux. All of these gentlemen were charter members of the Institute, and had maintained an active interest in its affairs, Major Michaelis and Mr. Shelbourne being in office at the time of their death. The third year of the Institute was now entered upon. It was still without a home, its only office being that occupied by the secretary, then engaged in other business. Meetings had been held but once a year, it being doubtful whether sufficient interest could be aroused to insure an audience. After a year's experience the secretary had fully satisfied himself that more frequent meetings were necessary in order to establish that general acquaintance among its members which he felt was essential to success. In order to bring out the members he had proposed to gather them at a dinner, after which a paper should be read and discussed; and he insisted that the plan should be adopted at once. At the annual meeting, May, 1886, when he announced his plans he was ably supported by Major Michaelis and Messrs. F. W. Jones, C. O. Mailloux, T. C. Martin, and F. L. Pope, the president. The first of these meetings was held in June, 1886, in the restaurant of the Mills Building, New York city, when Dr. Otto A. Moses addressed the meeting upon the distribution of electricity from central stations. The meeting was a success in every respect, and it was decided to continue upon the same plan in the autumn. Papers were read at these meetings by Mr. T. C. Martin and Dr. Schuyler S. Wheeler. At another meeting, held in March, 1887, the subject of the distribution of electricity by secondary generators was discussed. This meeting was especially noteworthy as being the first at which Prof. Elihu Thomson had spoken before the Institute, and few were aware until that time of the fascinating manner in which he so clearly makes known his researches.

His somewhat unexpected appearance was no less a surprise than the able manner in which he touched upon various electrical matters more or less identified with the subject under discussion. His subsequent papers—all of them classics—have added greatly to the prestige of the Institute, and it is safe to assert that no electrician of the day stands higher in the estimation of the members of the Institute than does Elihu Thomson. His first formal paper was read at the general meeting, May 18, 1887, on "Novel Phenomena of Alternating Currents." It was a profound research, and was extensively published through the electrical press. This movement toward advancing the Institute to a position where its true mission would be appreciated was not, however, confined to the election of active officers and the holding of more frequent meetings. With the assurance of support, two of



GEORGE M. PHELPS.

the charter members, who had an extensive acquaintance among electrical engineers, Messrs. T. C. Martin and Joseph Wetzler, undertook to personally enlist the support of a large number of their friends, so that at the annual meeting, May, 1887, the council had the satisfaction of announcing that at its meeting held that day ten new associate members had been elected. Nor did the reform movement halt at this point. Mr. T. C. Martin, who in 1885 had succeeded Mr. Keith in the office of secretary, was now brought forward as a candidate for the presidency. In a certain sense the move was an audacious one. Mr. Martin was a technical journalist, but did not claim in anywise to be an electrical engineer. His energy and ability, however, were fully recognized, and his supporters believed that a single year with such a man in the chair would lead to the final success of the organization. The results have fully justified the wisdom of this decision. Even those who stood in highest places as scientific and practical men rallied to the support of the new administration, for Mr. Martin's nomination had been followed by his election. The vigor of his administration was apparent from the outset. He had been familiar with the affairs of the Institute since its inception. He knew that the electrical business was in just that position where a stable electrical engineering society would inspire confidence in its future. It was one thing to be aware of this fact, but quite another to make the public see it. The adherents of one company were possibly suspicious, or perhaps jealous, of others. They were in many cases entire strangers. There was a clannish feeling that must be broken up. Nothing was needed but a common, neutral meeting ground, and this was just what the Institute proposed to furnish; and President Martin made it plain that the electrical fraternity must rally to its support.

The standing of the Institute was now fairly fixed. It had made a record, and now was the time to profit by it. President Martin and Secretary Pope worked in perfect harmony, and circulars were prepared and sent to every desirable electrical engineer whose address could be obtained. The tide had turned, and applications for membership began to flow in from all parts of the world. The monthly meetings, initiated as an experiment, had proven so successful that the monthly publication of their proceedings was begun in the fall of 1887, and since that time they have regularly appeared, forming, when bound, a handsome annual volume, having a portrait of a past president as a frontispiece. President Martin's term of office expired in May, 1888. He declined renomination on the ground that the object for which he had been elected had been accomplished; that the presidency of the Institute had become an honor which any man should set a high value upon, and that its welfare no longer depended upon the personality of any one man. Mr. Edward Weston, the well-known electrical engineer and inventor, was elected as his successor. The business affairs of the Institute had now attained such importance, and its publications required so much attention, that their proper administration conflicted with the other duties of the secretary. The growth in membership had supplied sufficient income to carry on the work more systematically, and an office established at 5 Beekman street, New York, was occupied by the secretary for two years. At the general meeting in May, 1888, another event occurred, the full significance of which has not yet been determined. This was the public description by Mr. Nikola Tesla of his "New System of Alternating-Current Motors and Transformers." Up to this time the alternating-current motor had been a kind of *ignis fatuus*. Mr. Tesla had made it a reality. The attention of inventors was directed to this subject, and they are still busy with it; for, although the idea was novel, and possessed the elements of success, it still lacked commercial applicability. Since that date inventors throughout the civilized world have directed their thoughts to the commercial adaptation of the alternating-current motor, and the now historic experiment of the transmission of power between Lauffen and Frankfort, a distance of 110 miles, is the natural development of Mr. Tesla's investigations. Nor did Mr. Tesla's work

end here. On the 20th of May, 1891, under the auspices of the Institute, he delivered a public experimental lecture at Columbia College on "Alternating Currents of Very High Frequency, and Their Application to Artificial Illumination." This was notably one of the scientific events of our day, and the investigations of Mr. Tesla aroused world-wide interest in the man, as well as his work. There have been many valuable papers read before the Institute, but none has borne more strikingly upon its face that stamp of originality, ingenuity, and perseverance which has made the name of Tesla the synonym for the highest type of the scientific investigator.

These important events in the history of the Institute are mentioned for the reason that they afford an excellent example of the good results arising from organized efforts for making public these remarkable researches, and affording a suitable channel for their presentation before appreciative audiences, and their subsequent publication for the benefit of the whole world. In this respect the Institute has at all times given the freest permission for the publication of its papers, so that all, whether members or non-members, may profit by its existence. In this policy its practice differs somewhat from that of several other similar societies; but it is believed that the general result is beneficial to the best interests of electrical development, and that the welfare of its members is thereby promoted.

Although a committee on permanent quarters had existed since the first year of the Institute, and an attempt had been made to unite with other societies in joint quarters, nothing came of it. In 1887 a movement was started to purchase a home for the Institute, and about $5000 were pledged for that purpose; but finding that a similar effort was being made by another electrical organization of a definite social character, it was deemed prudent to postpone the matter, and devote the income of the Institute to increasing its usefulness, trusting that the lapse of time would vindicate, as it has, the wisdom of this decision. In the winter of 1889-'90 the American Society of Mechanical Engineers engaged in a similar effort to provide itself with suitable quarters, and the proposition was made to the Institute that, should a house be purchased, the headquarters of the Institute should be established in the same building. With the assurance by the council that such an arrangement would be made, the mechanical engineers made the purchase of the house of the Academy of Medicine, and since June, 1890, the electrical engineers have been conveniently located at 12 West 31st street, New York city. Here they practically enjoy all the privileges of the house, having a joint use of the library and auditorium, with a separate office occupied by the secretary, where the files of 70 electrical and mechanical journals are kept, and in which the monthly meetings of the council are held. The practice of the Institute in holding monthly meetings has been found exceedingly beneficial, for the reason that electrical development has been so rapid that new topics are continually arising which are now brought before the Institute for discussion. Although distant members cannot always attend these meetings, copies of the papers are printed in advance, and members who desire to do so, wherever they are located, may contribute their remarks in writing. This practice is believed to be the nearest possible approach to the actual attendance of members at the meetings.

The total membership of the Institute on May 1, 1892, was 615. Its permanent growth, as shown by the date of election of the members now on the list, is as follows: 1884, 70; 1885, 7; 1886, 10; 1887, 115; 1888, 52; 1889, 84; 1890, 133; 1891, 109; 1892, (4 mos. to May 1) 35; total, 615.

It is a pleasure to note that the attendance at the meetings of the Institute and council is never meager, and great interest is taken by members and officers in its work. Its growth in membership is steady and healthy; and while the terms of admission to associate membership are liberal, the transfers to full membership are carefully guarded by the board of examiners, which performs no other duty, and is an entirely distinct body from the council. It is said that the Institute has passed a

smaller proportion of its membership to the upper grade than any other kindred society in the country. So long as no other means exist for the protection of the public from various imposters masquerading under the title of "electrician," the Institute has assumed the duty of establishing a professional standard which will gradually lead to the recognition of its members as being entitled to the confidence of their employers or clients.

Mr. George M. Phelps, who since May, 1887, has so satisfactorily performed the duties of treasurer of the Institute, is a son of the late George May Phelps, the well-known mechanician and inventor. His early commercial training in a bank has thoroughly qualified him for a position of this kind. Mr. Phelps is also treasurer of the Electric Club.

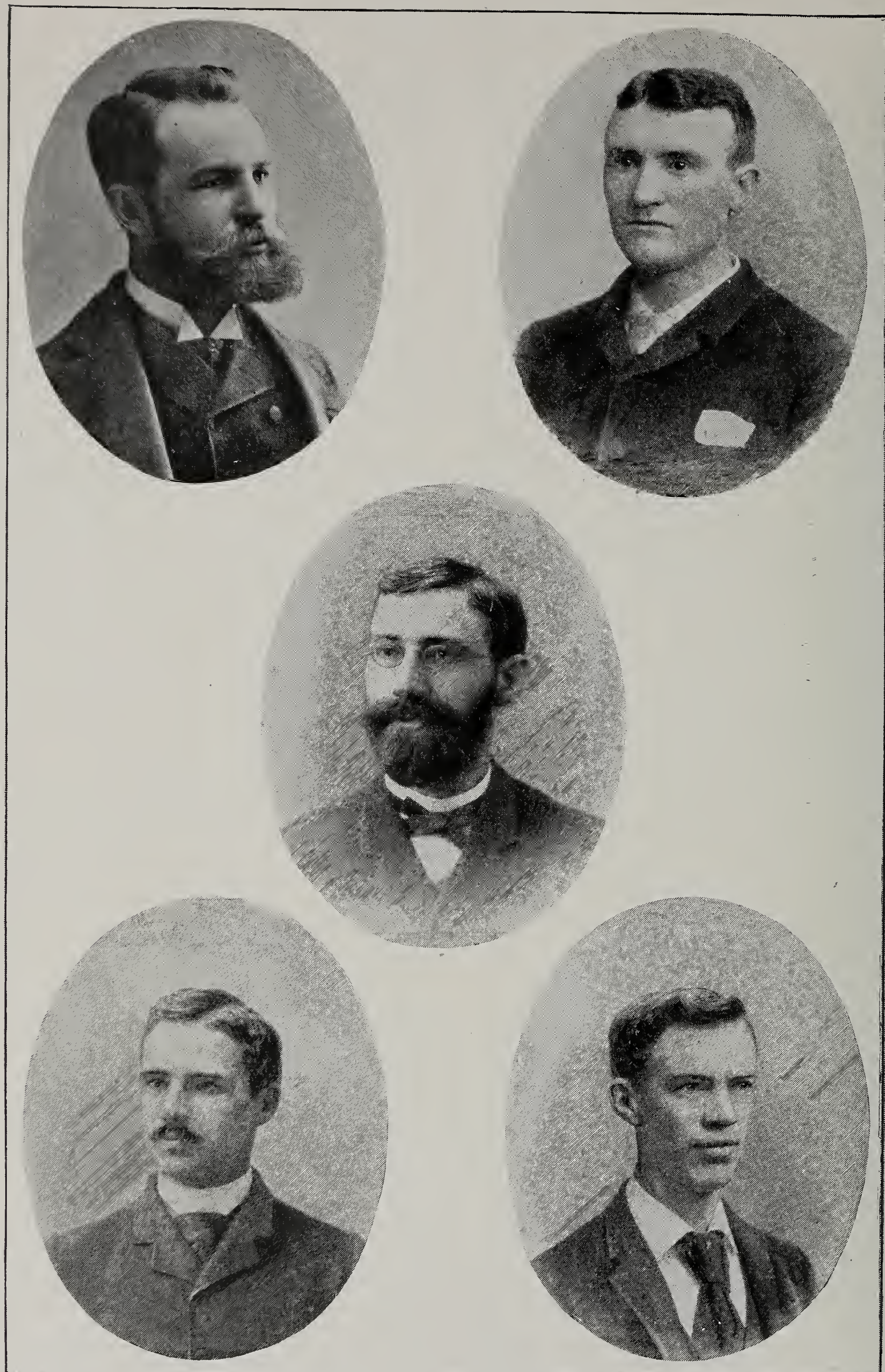
In May, 1889, Prof. Elihu Thomson was elected president, a deserved tribute to one whose scientific work had already done much to establish the prestige of the Institute. Prof. Thomson is an exceedingly busy man, yet he makes it a point to be present at the general meeting each year, either with an important paper or thoroughly equipped to take part in any discussion which may arise. His readiness to respond to any call which requires his presence, even at considerable personal inconvenience, has been of great value to the Institute.

In May, 1890, Prof. William A. Anthony, of Manchester, Conn., formerly of Cornell University, was elected president, and his conscientious performance of the duties of his office was most heartily appreciated. During his term of office he never failed to preside at every meeting, although his presence necessitated a considerable journey for that purpose. It is interesting to note that his is the first portrait presented to the Institute, and the hope may be expressed that the admirers of other presidents will follow the example thus set.

It has been the unwritten law of the Institute that the various electrical interests should be represented in its management as far as consistent with the proper prosecution of its work, and in 1891 Alexander Graham Bell, inventor of the speaking-telephone, was elected president. It was understood at the time that he could not give personal attention to the duties of the office, and he has been ably represented by Vice-President Thomas D. Lockwood, of Boston, who has usually presided in his absence, and has, in fact, discharged well-nigh all the duties of the office.

As the holding of an international electrical conference in 1884 was largely instrumental in influencing the organization of the Institute, later congresses, at Paris in 1889 and in Frankfort in 1891, have afforded an opportunity for the proper representation of America at these important gatherings. Delegations from the Institute were accordingly appointed by the council, which participated in the proceedings. In 1890 the Institute took up the question of commemorating the scientific discoveries of Joseph Henry by recommending that his name be given to the unit of self-induction. This proposition was not definitely accepted by the Frankfort Congress, but will be brought up again at the World's Electrical Congress to be held in Chicago in 1893, and its universal adoption will be strongly advocated on that occasion, which will, in all respects, be the most important electrical conference ever held.

At the last annual meeting, held in New York city, May 17, Mr. Frank J. Sprague was elected president, having just completed a term of two years as vice-president. Mr. Sprague was born at Milford, Conn., July 25, 1857, most of his boyhood being spent at North Adams, Mass. He entered the Naval Academy at Annapolis in 1874, having secured the appointment by a competitive examination. He completed his electrical studies at the Stevens Institute of Technology, and was afterwards detailed to the Newport Torpedo Station. In 1882 he reported upon the Crystal Palace Electrical Exhibition for the government, and was the only American on the jury, of which he was secretary. In 1884 he joined the Edison ranks, and his name has since been prominently identified with electrical railway work, his first important victory in this field being the construction of a street railway at Richmond, Va., which, considering the difficulties that were necessary to be overcome, was a wonderful achievement. Mr. Sprague is a member of the firm of Sprague, Duncan & Hutchinson, consulting electrical engineers, and is devoting his attention largely to the heavier class of work which electricity is now being called upon to perform.



PROFESSORS AT PURDUE UNIVERSITY.

JOHN J. FLATHER, PH.B., M.M.E., Professor of Mechanical Engineering.
MICHAEL GOLDEN, Professor of Practical Mechanics.
WILLIAM F. M. GOSS, M.S., Professor of Experimental Engineering.
ALBERT P. CARMAN, A.M., D.SC., Professor of Physics and Applied Electricity.
ALFRED E. PHILLIPS, C.E., A.M., Professor of Civil Engineering.

THE PURDUE UNIVERSITY.

TECHNICAL SCHOOLS OF AMERICA.—II.

By Professor W. F. M. Goss.

PURDUE University, one of the principal technical educational institutions, is located at La Fayette, Indiana, a city of about 20,000 inhabitants. La Fayette was settled very early in the history of the state, and is situated on the banks of the Wabash river near the site of the old French trading fort Ouiatenon, which more than a hundred years ago made one terminus of the line of portage between the waters of the great lakes and those of the Mississippi. Within easy driving distance is the historic battle-ground of Tippecanoe, whose massive oaks and hickories still bear the scars of wounds received in that frontier fight when the trees served as shields for white man and red man by turn.

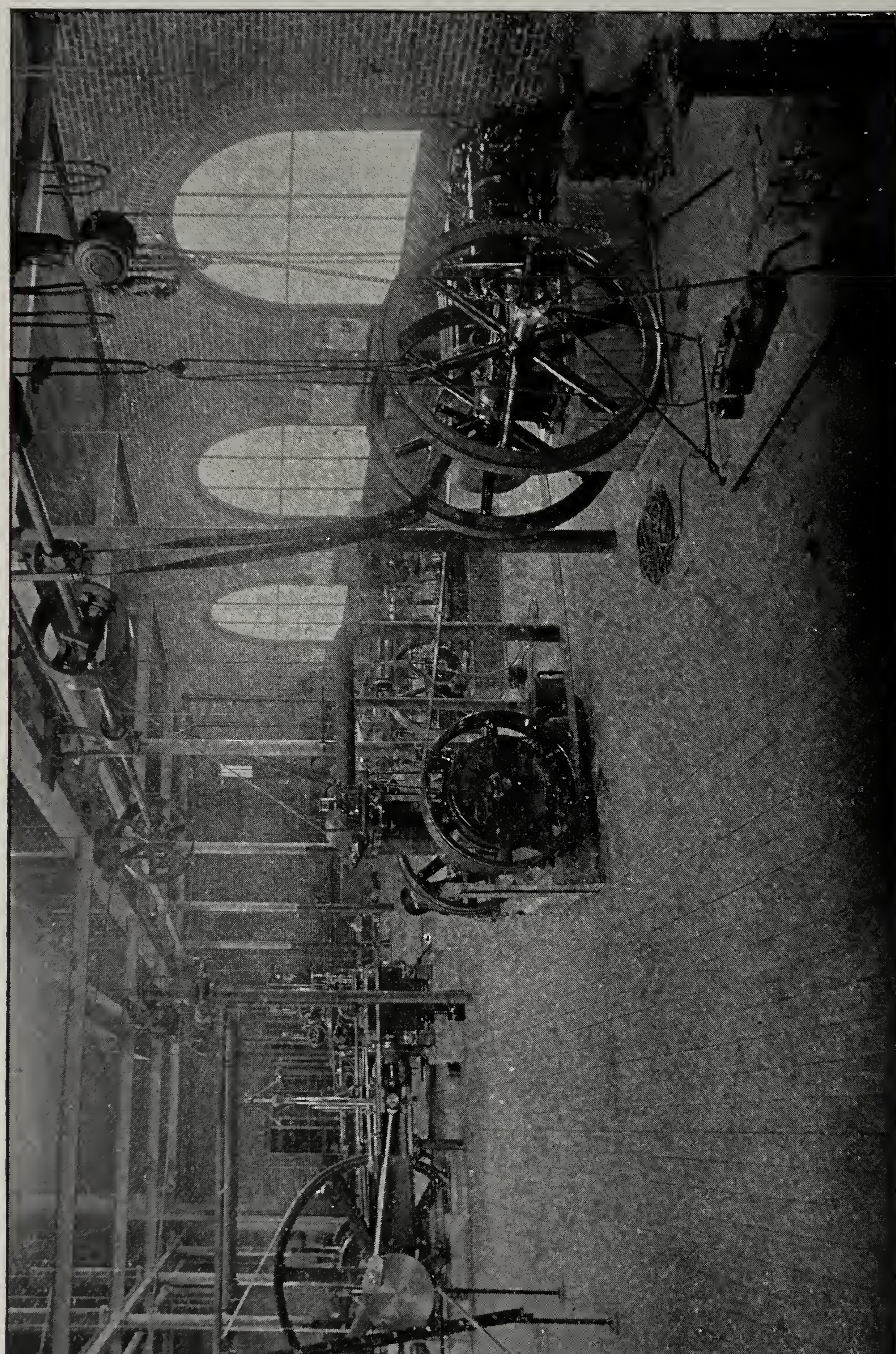
The university domain comprises 180 acres. The grounds are at a considerable elevation above the river, which is a mile distant. The buildings are 18 in number, and contain recitation rooms, museums, library and reading rooms, and well-equipped laboratories. The college department embraces a school of mechanical engineering, a school of civil engineering, a school of electrical engineering, a school of agriculture, and a school of science.

It is the purpose of the present article to describe, somewhat briefly, the special equipment and work of the schools of mechanical, civil, and electrical engineering.

The technical work of all engineering students during the early part of their course at Purdue is such as will give a fair degree of skill in the processes of machine construction.

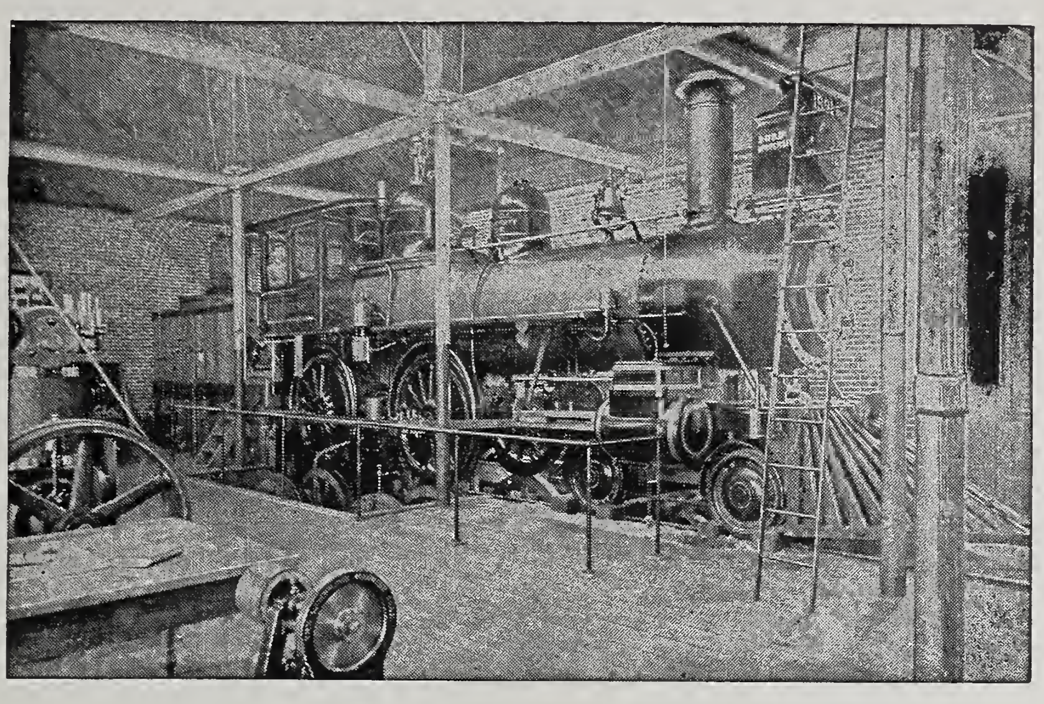
Preliminary practice in making joints at the bench, and in turning at the lathe, is followed by systematic work in pattern-making, molding, and casting; and this, in turn, by forging and machine work. All work is done from drawings by means of the usual shop tools and machines. This "shop practice," as it is commonly called, takes its place in the course during the freshman and sophomore years, and ranks as any other one study. It requires a total of about seven hundred hours' practice, or as the apprentice would count it, seventy days, and it gives that intimate acquaintance with materials and processes of construction which is so essential to the success of the designing and managing engineer. It enables him, for example, to carry any part of a machine through every stage of its construction. From the drawing he can make the wooden pattern ; from the pattern, the mold ; from the mold, the casting ; and from the casting, the finished part. Similarly, if the part required is to be of wrought metal, he can forge and finish it to form. All this is done not to turn out skilled pattern-makers, blacksmiths, or machinists, but rather that men who are to receive training in the higher branches of designing may be guided by an intelligent understanding of the limitations within which they must work.

The product of the shops is to be



ENGINEERING LABORATORY. CORLISS, WESTINGHOUSE, AND GAS ENGINES.

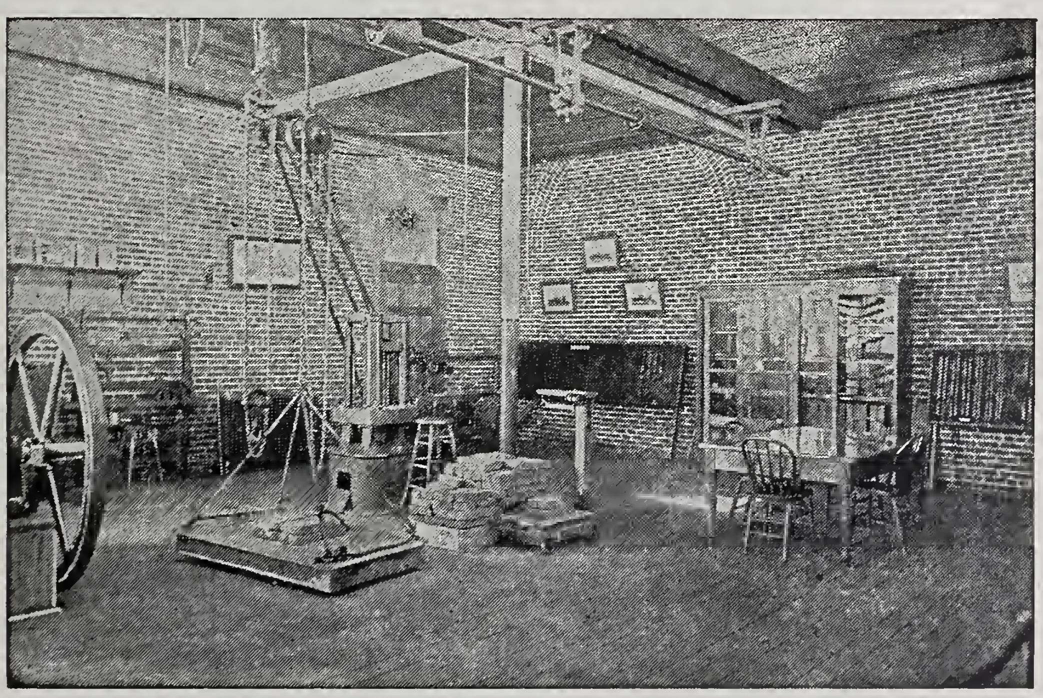
looked for in the increased excellence of the student's advanced work rather than in the material things he has constructed. Incidentally, however, many useful machines and appliances result from these laboratory courses. The laboratories for this work occupy the Practical Mechanics Building.



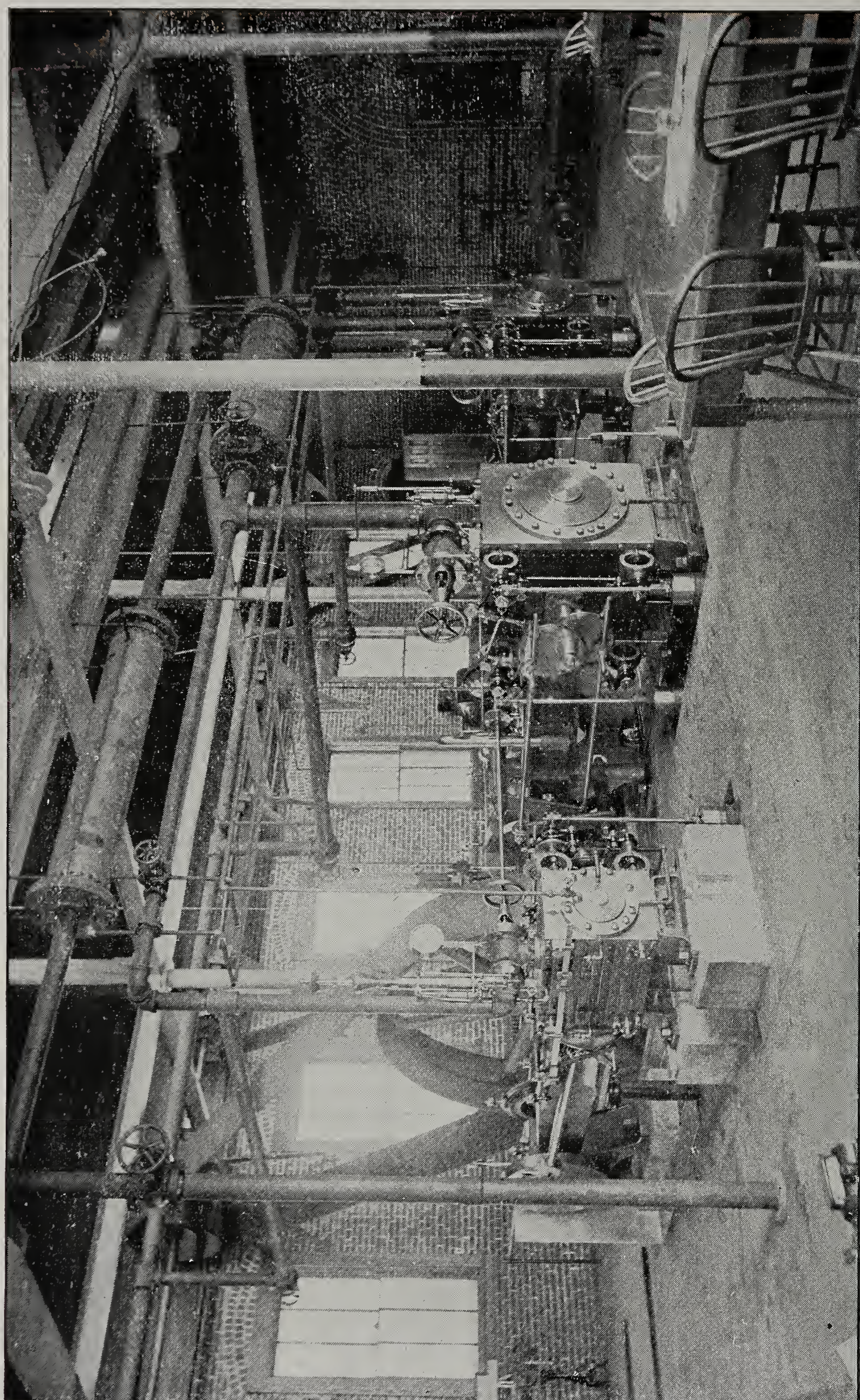
ENGINEERING LABORATORY. 17 X 24 SCHENECTADY LOCOMOTIVE.

The wood-working room has in it 40 benches, with sets of tools for 100 students; 21 lathes for wood-turning, with tools for 100 students; circular, band, and scroll saws, as well as small tools needed in pattern-making.

The foundry contains 30 molding benches, with tools required in molding, a cupola furnace for iron, a brass furnace and a core oven, and is also supplied with the sand, flasks, facings, etc., required in bench- and floor-molding. Adjoining is a small room equipped for core-making.



ENGINEERING LABORATORY. OLSEN TESTING MACHINE.

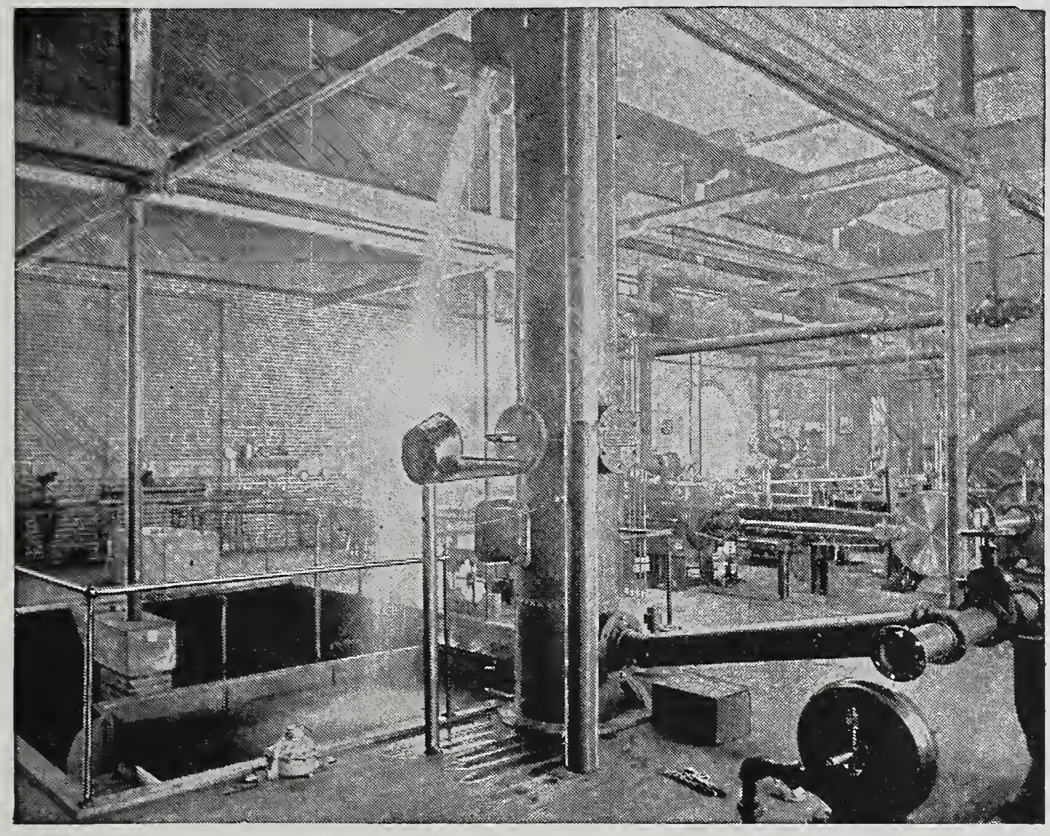


ENGINEERING LABORATORY. TRIPLE-EXPANSION HARRIS-CORLISS ENGINE.

The forge room contains 24 forges, with smithing tools, and is fitted with blast- and exhaust-pipe systems.

The machine room has 14 screw-cutting machine lathes of different sizes and makes, several speed lathes, a universal milling machine, two vertical drills, cutter and tool emery-grinders, and 25 vises, with small tools for hand work in metal.

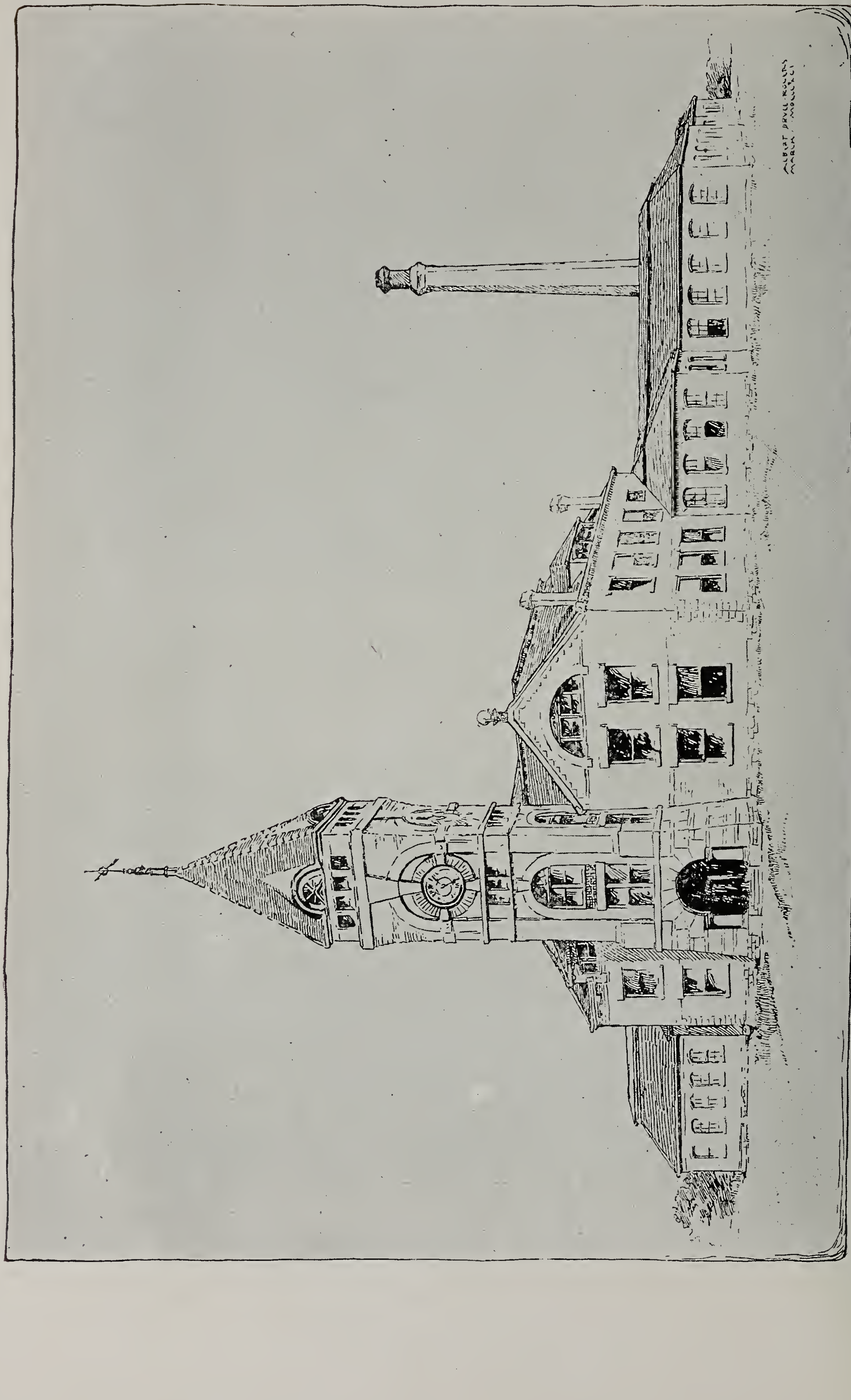
A tool room is provided with special tools needed by the wood- and iron-workers, for which there is only occasional use. It also contains the small supplies used in the various rooms. Motive power for shops is furnished by an automatic cut-off engine of 35 horse-power.



ENGINEERING LABORATORY. HYDRAULIC APPARATUS.

ENGINEERING LABORATORY. HYDRAULIC APPARATUS.

During the freshman and sophomore years the mechanical drawing accompanying the shop work includes free-



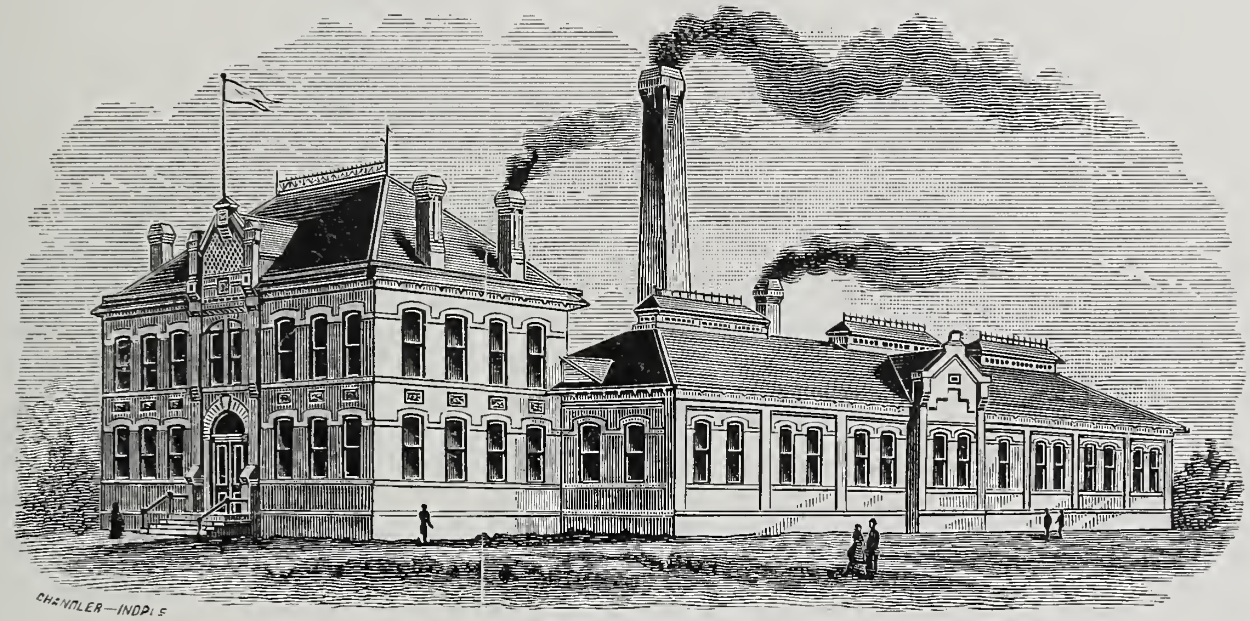
DESIGN OF NEW MECHANICAL LABORATORY.

hand drawing, drawing from copy of details of machines, drawing to scale from parts of actual machines, ink shading and tinting; also practice in the development of problems in descriptive geometry. This work is carried on in a large room furnished with 150 specially designed drawing tables.

Beginning with the junior year, and continuing throughout that and the senior year, the technical work of different engineering courses is quite distinct. Thus students in mechanical engineering, while studying the elements of mechanism, machine design, strength of materials, steam engine, and kindred subjects, are instructed in the drawing rooms in the methods of developing in detail the parts of new machines and in designing machines to perform stated operations,—as, for example, steam engines, boilers, hoisting machinery, and arrangements by which power may be transmitted. The civil engineers meanwhile supplement their class-room work by making designs for bridges, roofs, standpipes, piers, and foundations; and, in connection with their outside field work, by developing plans for roads, railroads, water-supply systems, and sewage systems. At the same time the electrical engineers give their chief attention to studies bearing on electrical machinery,—motors, dynamos, etc.,—and to practice in designing such machinery.

The drawing rooms for this advanced work are furnished with convenient tables with lock drawers, in numbers sufficient to avoid the necessity of assigning more than one student to a table. In the possession of his place in the drawing room each student has virtually a private desk, to which he may retire for reading or for work during any unoccupied hour that he may chance to have.

After the shop work of the freshman and sophomore years the engineering students enter upon the most fascinating part of their course,—work in the advanced technical laboratories. This continues during the junior and senior years. Here they carry on an experimental study of the action of machines, and of the economic problems which this action suggests; in short, are given practice in just such work as, after graduating, they may be called upon to do when serving as practicing engineers.



LABORATORY OF PRACTICAL MECHANICS.

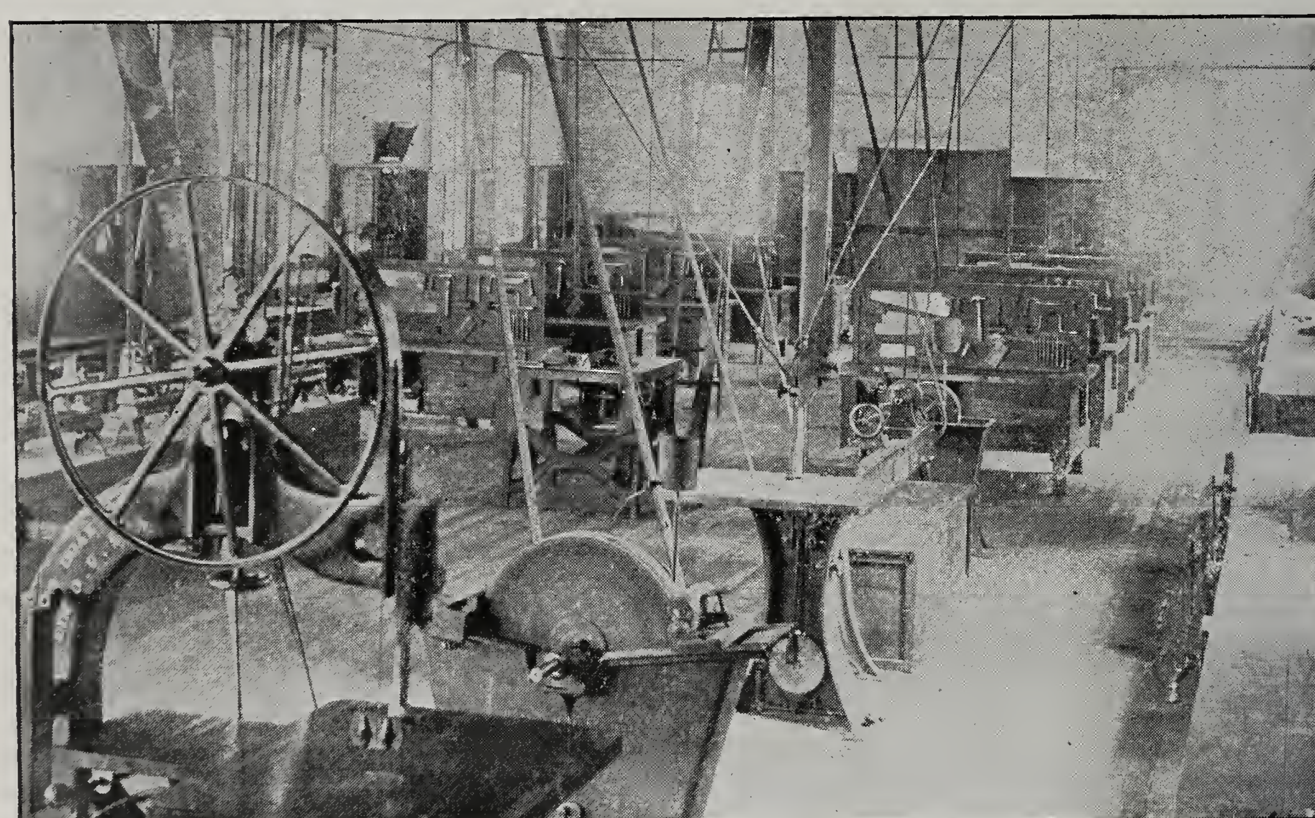
Formerly it was the custom of institutions similar in purpose to that of Purdue to equip their laboratories for advanced engineering work with small apparatus, really no better than models of the types represented. But the question as to the cost of operating a small machine is an unimportant one, for the expense is small. What is most needed is to study methods of running large machines effectively and economically, and the problem is unsatisfactory when

worked out on small ones; for in most cases it is impossible to base an estimate as to the probable behavior of the former upon results obtained by trying the latter. Hence the necessity for large apparatus in a students' laboratory.

The Purdue laboratories are fitted with commercial machines of fair representative size, and in their purchase selections have been made from makers of recognized merit. The necessary accessory apparatus and the instruments of precision used in testing these machines are also from the best makers. An effort has been made to secure for each class of work as great a variety of apparatus as practicable, and additions to the outfit are made each year. For example, in the engineering laboratory there are 18 engines of different forms, and in the electrical laboratory a half-dozen different electrical systems are fully represented.

The engineering laboratory occupies a room 50 x 110 feet, and there is a boiler room attached, 25 x 40 feet. The character of its equipment may be seen by reference to the following enumeration, which includes some of the more important pieces of apparatus which have thus far been put in place.

A 100 horse-power Harris-Corliss triple-expansion steam engine has been designed and constructed especially for this laboratory. The engine cylinders are 8, 15, and 22 inches in diameter respectively, by 24 inches stroke. The pipe connections are such that any of the cylinders may be worked singly, or they may be worked in combination under any one of six possible arrangements. The steam jackets of the cylinders and of the intermediate receivers may be thrown out of use at will. The crank of the high- and of the low-pressure cylinder may be set at an angle of 90, 120, and 180 degrees with that of the intermediate cylinder. Connected with the engine are a surface condenser, an independent air-pump, tanks on scales in which may be weighed the condensed steam given up by the engine, tanks on scales in which may be weighed the cooling water which passes the condenser, permanent indicator rigs, and the usual gages and counters. A 104 horse-power boiler, having its safety valve set at 160 pounds, supplies steam



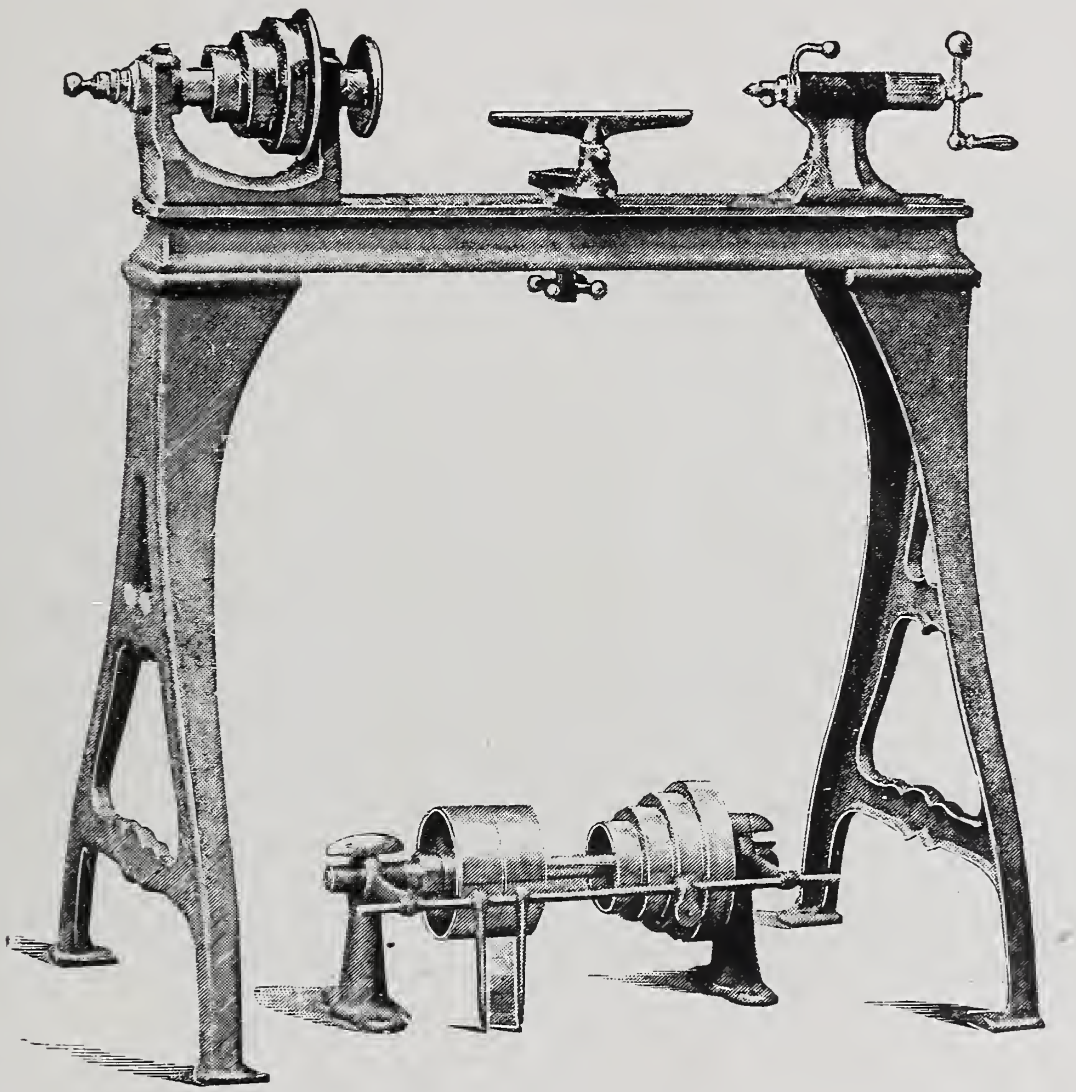
LABORATORY OF PRACTICAL MECHANICS. WOOD-WORKING ROOM.

at high pressure for the triple-expansion engine and for general purposes. Accessory appliances are provided for use in making boiler tests.

A 17 x 24 locomotive, weighing 85,000 pounds, is mounted upon supporting wheels in the laboratory in such a way as to allow its action to be studied and its performance tested while the engine is run at any desired speed or load, the conditions being similar to those of the track. The power of the engine is absorbed by powerful friction brakes, and its tractive force is measured by a suitable dynamometer attached to the draw-bar. The boiler may be fired with coal in the usual way. A powerful steam blower above the engine, but not in pipe connection with it, takes up and carries off whatever may be given out from the locomotive stack.

A 12 horse-power gas engine, especially arranged for experimental work, is supplied with natural gas from the same pipe which feeds the fire under the fixed boiler. Means are thus afforded not only for carefully testing the performance of the gas engine, but also for making a direct comparison of its efficiency with that of the steam engine.

For work in applied mechanics, there is a 100,000-pound testing machine driven by power, for determining the strength of constructive materials under tensional, compressional, and transverse stresses; a 2000-pound cement tester, for determining the relative value of cement and cement mortars; and a good supply of vernier and micrometer calipers, scales, and gages.

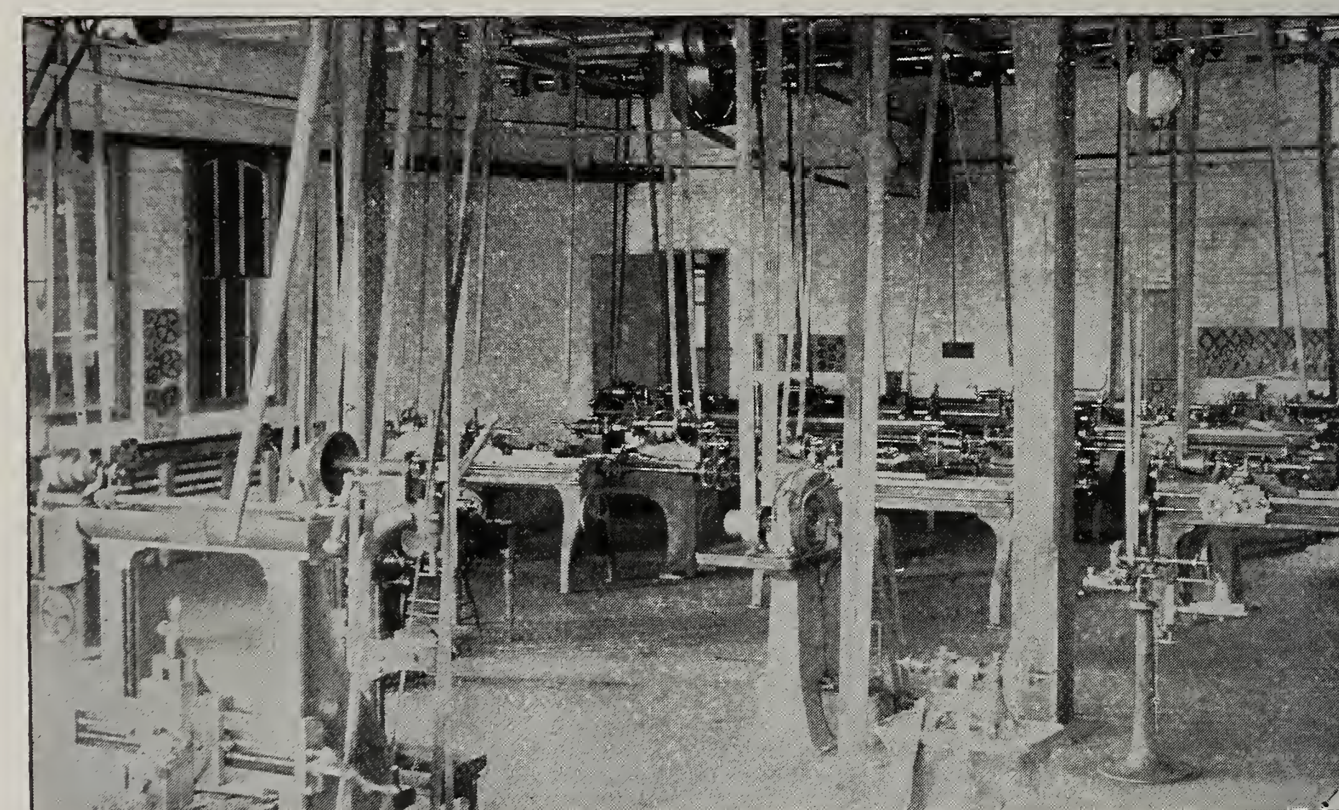


HAND-LATHE MADE BY STUDENTS IN PRACTICAL MECHANICS.

For work in hydraulics, there is a direct-acting steam pump, two centrifugal pumps, a turbine water wheel, two water motors, and apparatus for measuring the flow of water over weirs, in pipes, and through orifices. A steam pump delivers the water supply from a well to a storage tank of 1000 barrels

capacity, and an experimental standpipe affords means for maintaining any desired range of water pressure.

For civil engineering, in addition to much which has been described as constituting the equipment of the engineering laboratory, there are four complete sets of field instruments by different makers, including transit, level, chains, rods, tapes, etc. In addition to these, for fine field practice and geodetic work there is a 10-inch alt-azimuth instrument, made to order for the department. There are also models of various types of bridge and roof trusses in wood and iron.



LABORATORY OF PRACTICAL MECHANICS. MACHINE ROOM.

The electrical laboratory is in a special building, having facilities for exact experimental work. The dynamo room contains a 22 horse-power "straight-line" steam engine and the following dynamos and motors: An original French gramme, a Thomson-Houston arc, a Brush arc, an Edison incandescent, a Slattery alternator, a 5 horse-power Perrett motor, a 5 horse-power Thomson-Houston motor, and several smaller motors. A large Brackett cradle dynamometer, a bank of incandescent lamps, resistances for large currents, photometric apparatus, and other testing appliances have been provided. With the usual commercial testing bridges, ammeters and voltmeters, there are also the finer pieces, such as a Kew magnetometer, two Thomson balances, a Thomson quadrant electrometer. 10 of the best mirror galvanometers, standard resistances, and electro-dynamometers.

For the development of Purdue's extensive laboratory system too much credit cannot be given to the management of Dr. James H. Smart, the president of the university, who has been untiring in his efforts to provide for students the best possible training for future scientific and industrial work. In these efforts he has had the co-operation of an appreciative board of trustees.

The engineering chairs at Purdue are filled by W. F. M. Goss, professor of experimental engineering and director of the engineering laboratory; J. J. Flather, professor of mechanical engineering; A. E. Phillips, professor of civil engineering; A. P. Carman, professor of physics and applied electricity; and M. J. Golden, professor of practical mechanics.

James H. Smart, A.M., LL.D., who is the president of Purdue University, has had for the past thirty years an important influence in encouraging and shaping the progress of education in Indiana. For several years he was associated with the public schools of different cities in Ohio and Indiana, and the present excellent public-school system of the latter state is largely due to the foresight and judgment exercised during the time when he was State Superintendent of Public Instruction. In 1883 he was elected to his present office. Here his energy, tact, and executive ability speedily became apparent. During his administration the influence, scope, and equipment of the university have increased at least four-fold. Although the various departments are in charge of experienced professors, the excellence of the work done depends in a greal degree upon the president's skill in securing means for its prosecution, and upon his wise plans for its general development.

The professor of physics and electrical engineering, Albert P. Carman, A.M., D.Sc., is a graduate of Princeton, where, also, he was a fellow in experimental science, acting instructor in physics, and for two years tutor in mathematics. Later, at the University of Berlin, he studied two years under Helmholtz and Kundt. He received his appointment at Purdue in 1889, and under his direction the present electrical laboratory building, with its splendid facilities for experiment and research, has been fitted up and equipped.

THE ELECTRICAL LABORATORY.

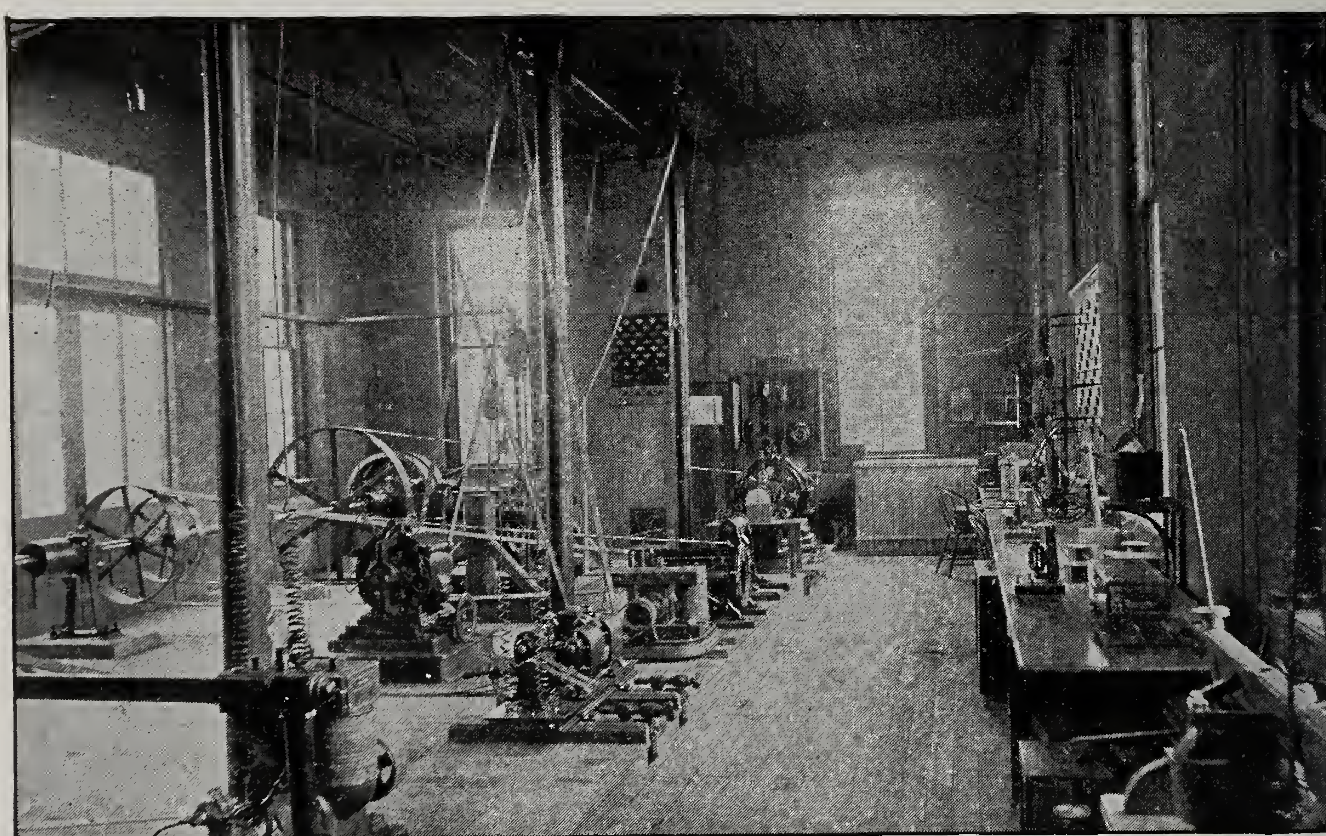
A man of practical as well as of scientific attainment has been obtained for the professorship of mechanical engineering, in the person of John J. Flather, Ph.B., M.M.E. When quite young he studied abroad. Later he spent five years in various New England shops as machinist, foreman, and draughtsman.

In 1885 he graduated from the Sheffield Scientific School of Yale University, and afterwards was employed as a designer of special machines for the Electrical Supply Company, of Ansonia, Conn., and still later as superintendent of the Buffalo Steam Pump Works. In 1888 he became instructor in mechanical engineering at Lehigh University, where he remained until 1891, when he was called to Purdue. Professor Flather is the American editor of Wilson's "Steam Boilers," and the publisher of a hand-book on "Mechanical Technology of Machine Construction." More recently he has written a "Treatise on Dynamometers and the Measurement of Power," which has just been issued by Messrs. Wiley & Sons. In his one year at Purdue he has done much to stimulate interest in his department, especially by his work in machine design, into which his wide experience gives him the advantage of being able to introduce practical shop methods.

The professor of practical mechanics, M. J. Golden, has greatly systematized the work over which he has charge, and as a consequence the courses have much improved under his administration. Professor Golden was two years at the Massachusetts Institute of Technology, and one year instructor in mechanical drawing and mathematics at the Hyde Park High School. He was appointed instructor of practical mechanics at Purdue in 1884, and to his present position in 1890.

Alfred E. Phillips, A.M., C.E., professor of civil engineering, is a graduate of Union College. He served for a time as assistant engineer with the Cumberland Valley & Unaka Railway Company, and later occupied a similar position with the New York State Board of Health during an investigation of the sanitary condition of the New York city water supply. In 1887 he was elected to the then new chair of civil engineering at Purdue, which he has since occupied.

Under his direction the original scope of the school has been largely shaped, and year by year valuable apparatus added and the range of work extended.



ELECTRICAL LABORATORY. DYNAMO ROOM.

VARIOUS KINDS OF ENGINEERING.

By Robert Grimshaw, M.E.

IN these days there are so many kinds of engineering, and their principles and practice are so overlapped and interwoven, that it is sometimes puzzling to know where one begins and the other leaves off; and many a good man, when called upon to state his business, either to a directory fiend or in court, finds himself in a quandary. Recently the writer contributed the definitions of the term "engineering" for a standard dictionary, and it may be interesting to know how many kinds of engineering there are, and on about what lines they may be defined.

Engineering in general may be fairly well defined as the science and art of making or building, or of using, engines and machines, or of designing or carrying out the construction of public works requiring special knowledge of constructive materials or machinery, or of the laws of mechanics. No definition of the term "engineering" can be given except by a treatise on the various branches of the science. If a treatise were written upon each, considered by itself, and also in relation to the others, whoever read it would be able, after reading it or studying it, to form a fair idea in his own mind of what engineering was; but that he can convey it to another except by writing for him another treatise, or by recommending him to read the one already written, is very doubtful.

The principal branches of engineering, mentioned in their alphabetical order, are civil, dynamic, electric, hydraulic, marine, mechanical, military, mining, naval, steam, and topographical, which every typewriter in the United States seems to be bent on writing typographical, and that is the way most of the printers allow it to appear.

The term "civil engineering" in America applies to the science and art of designing and constructing public works, as roads, bridges, canals, railways, water-works, harbors, drainage systems, etc. This alone is a great range; but many civil engineers practice in all the branches, while others devote themselves, or get devoted, to some specialty. There are able engineers who eat, drink, and sleep roads; others who from the rising of the sun until the going down thereof bridge streams, inlets, ravines, streets, etc.; others again make harbor improvements their life-object; and piers, dry docks, and the like engage others' talents and others' attention. But in some parts of the country the word "engineer" means little more than a surveyor,—sometimes the most ordinary kind of surveyor at that: a man able to drive a copper tack in a stump and tell you that that is your corner, and beyond that is the other man's. Between the great lines of the civil engineering profession and the followers of such a modest branch of the science there is of necessity a great gulf fixed; and either Roebling, the great engineer of the Brooklyn bridge, or the country surveyor is classed about the same.

In Europe the term "civil engineer" means something different. The writer had considered himself a mechanical engineer in this country for about 13 years, and as one of the founders of the American Society of Mechanical Engineers had been duly enrolled as a member of that body; but he went to France, and was made an active member of the French Society of Civil Engineers, and since then, about another 13 years, he has been wondering which he is, mechanical or civil. Members of the society just mentioned have been elected members of the British Association of Civil Engineers, and are probably in the same quandary as to just at what point on the ocean they cease to be merely mechanical and take upon themselves the sweeter sound of civil.

As a matter of fact, any good civil

engineer, as he understands the term, finds himself called upon to know more than a little about mechanical engineering pure and simple ; besides which there are many branches of knowledge, such as the strength of materials, which both have to learn. When the American Society of Mechanical Engineers was started it was proposed by Prof. Trowbridge that they style themselves dynamic engineers ; but thinking that most of the members were a little afraid of it as being rather in advance of their day and generation, the writer, for one, opposed it, although, perhaps more than any one else in the room at the time, he seemed to be limiting himself to purely dynamic problems as far as mere engineering practice went. On Prof. Coleman Sellers's letter-head he is down as E. D., and probably that very competent gentleman, known to nearly everybody for so many years as one of the first mechanical engineers in the country, has been called upon several thousand times, more or less, to state what that meant.

Dynamic engineering is the science of mechanics as applied to the generation and transmission of power, the designing and construction of machines, machine tools, etc.

In these days the term "electric engineering" is coming to the front. That seems to mean both the science and the art of the application of electricity to engineering work. These two lap over each other. The railway "engineer of bridges and stations" finds himself called upon to know more than a little about electricity in the way of operating his signals. The ordinary everyday engine-runner, who is called an engineer, and is down in the directories as such, finds that unless he becomes something of an electrical engineer he loses his job of engine-running ; for he has the dynamos to attend to, sometimes the wiring to look after also, and more than seldom has to attend to the electric lamps as well.

The hydraulic engineer is called in France a hydraulician. To the writer's knowledge there has been only one American professional hydraulic engineer who hung out the sign "hydraulician," and that was a young Philadelphian who had been educated in one of the best French engineering colleges ; but he hauled in the sign when he found that people did not know what it meant. Probably it sounds so like statistician, and that seems very dry and abstruse.

Hydraulic engineering is the science and art of the application of the principles of hydraulics in such lines as the design and construction of water works, the development of water power, the construction of dams, sea-walls, etc. See how that trenches upon civil engineering. The civil engineer and the hydraulician meet at the dam or the sea-wall.

Marine engineering treats of the application of mechanics and engineering to the design and the construction of engines for ship propulsion. The marine engineer must be a steam engineer, and a dynamic engineer, and perhaps a naval architect, all rolled into one ; and if he wishes to be successful it will not do him any harm to be something of a hydraulician, that he may better understand the various kinds of feathering paddle-wheels, balanced rudders, and patent propellers which are brought out from year to year.

Mechanical engineering—the science and art of the application of mechanics to the designing, construction, and operation of machines and machine tools, and which is in Europe very close in many things to civil engineering—is here first cousin to dynamic engineering, for the two are not equivalent. There are many mechanical engineers who are dynamic engineers pure and simple ; others are very little else than machinists, and, indeed, in some countries there are "machinist engineers," as distinct from mechanical engineers, although there seems to be no way to indicate the profession of the machinist engineer as distinct from that of the mechanical engineer. The mechanical engineer should know about the strength and proper use of the metallic and many of the non-metallic materials of construction, and should have a well-grounded knowledge of electricity as applied to the industries. In mechanical engineering there arise at times problems which convey well in the province of the hydraulician, as, for instance,

in the designing, building, or erection of pumps and pumping machinery.

Military engineering, the science and art of the application of the principles of mechanics and engineering in designing and constructing the fortifications, military roads and bridges, surveying the topography (not typography, be it understood) for offensive and defensive military purposes, etc., calls for considerable engineering knowledge and kindred information and experience. To design a line of fortifications requires a knowledge of mathematics and of civil engineering. Road-making calls for surveying proper and for road engineering as well. Military bridges cannot be designed and put up without a knowledge of the science and the art of designing, constructing, and erecting such structures, although the experience gained as civil engineer in making permanent structures would be of very little avail here, where a bridge is good enough to all practical purposes if it lasts thirty days,—sometimes only as many hours. The military engineer must know something about ordnance and the strain to which it is subjected in use, about projectiles and their projectors, and all the various explosives, ordinary and high, which are being put upon the market.

Naval engineering is very largely the same as marine engineering.

Steam engineering, the science and art of the application of the principles of mechanics and engineering to the design, construction, and use of steam engines, boilers, and their appurtenances, shades off into mechanical and dynamic engineering in such a way that the lines cannot be defined.

Topographical engineering (with the *o*, and not with the *y*) is engineering as applied to the surveying of a country or district with the object of noting and recording its variations of level and contour, its water courses, canals, etc. Here, then, is surveying and civil engineering overlapping each other, and having a common shading off into other sciences and professions. It seems to be necessary for the military engineer to know more than a little about topographical engineering. To be successful in any one of them demands a good groundwork of theory, with the opportunity for varied practice. It is seldom that any one taking up the study and practice of any one of these lines can locate for himself which line he will follow to the exclusion or partial exclusion of others. As a general thing, young engineers take what business is brought to them. If their preliminary groundwork is good they are just about as apt in learning one branch as in learning another, and they are just as likely to get business in one line as in another. Many a young man has started out to be a military engineer, and has found that there were personal reasons why he would prefer to get out of the army and try a broader field. Others have started out as civil engineers, have gone into the army on a pinch, from patriotism or because there has been no other offer, and have stayed in the army and become military engineers, ready to go where sent and to do what was ordered or what was necessary or desirable in any one of a dozen branches of military engineering.

There is really no royal road to any one of them, other than what any young man who has the opportunity for a good education, and for serving a competent chief, may make for himself.

STEAM AND ELECTRIC POWER.*

By J. J. Wright.

I WILL venture to offer a few suggestions on the distribution of electricity for power purposes, which I hope may prove of benefit to those of our members who may contemplate the introduction of such a system. Firstly, then, your power has to be produced ; and if you wish to do an extensive business by supplying power at a reasonable rate, or if you have to meet competition, you must figure to produce it at the lowest possible cost. To allow for the various losses in converting your power into electricity and re-converting in the shape of power again, you will always have to produce a certain percentage more than you recover. Economy in the prime mover is therefore more than ever a necessity. You are a happy man if you possess a water power within reasonable distance of a fairly good market, but it seems to me that water powers, as a rule, for some inscrutable reason, are usually located in very inaccessible places. Power you must have. Wind is out of the question, and water having failed, we must fall back on our old friend, the steam engine. I am not going to thrash out the obsolete controversy of high-speed engine versus slow-speed. The question has been settled long since. Be moderate in all things. While you are avoiding the high-pressure, steam-eating flyer on the one hand, do not go to the other extreme and build an unwieldy engine that makes one revolution to-day and another to-morrow. Five hundred horse-power is about all you should employ in a single unit, but of course the size of engine will be governed very largely by the extent of the power plant you propose to install. But here let me give you a special piece of advice. If you honestly think 100 horse-power will be enough for the demand upon you, make it 200. If you think 200 will suffice, make it 400, and you will come out about right in the end. If you have no water for condensation, be very cautious about meddling with a compound engine. Unless the load is accurately proportioned to the size of the engine, the low-pressure cylinder will be a positive detriment ; and it is well known in this respect a power circuit fluctuates very widely. If water for condensation can be obtained, by all means use a compound condensing engine ; but if you do so, and have a good boiler and carry at least 125 pounds of steam pressure, make the diameter of the low-pressure cylinder larger than the common practice,—in fact, nearly as large as the third cylinder would be in a triple-expansion combination. I have very strong doubts whether the middle cylinder in a triple-expansion engine is any good at all. It is an open question whether the slight saving of steam by the uniform temperature of the cylinder is not more than overbalanced by the increased complication, weight, and friction of the extra moving parts. The reason for the existence of a triple-expansion engine is that it is the outcome of a gradual evolution,—first the high pressure, then the compound, then the farther use of the steam to ensure the benefit of the vacuum in a very large area of piston in the final cylinder. Now drop the middle cylinder and use a large low pressure in proportion as a compound. You will get the benefit of a vacuum over the increased area, and you will find equal results will be attained with less proportionate wear and tear and risk of accident.

Now another point. If your engines are of considerable size, and a compound

* From a paper read before the Canadian Electrical Association, at Hamilton, Ontario.

of the proportion spoken of would have a comparatively heavy low-pressure piston, place them upright. They will take up less room, and instead of having a heavy piston of a ton or a ton and a half weight dragging along the bottom of the cylinder, you have it floating in the center. Wear and tear is reduced to a minimum, and large economy in fuel and oil is the result. Let your engines move lively, but at a reasonable speed, say from 85 to 90 revolutions for a 250 or 350 horse-power engine ; or to express it in a better form, say at about 600 feet of piston speed per minute. If circumstances compel the use of high-pressure engines, see that they are large enough to have plenty of room to take the utmost benefit from the proper expansion of the steam. An engine to be economical should not carry more steam than from one-eighth to one-quarter of a stroke at the outside.

Having a steam plant that we can depend on producing power at the lowest possible figure, we must turn our attention to the question of its distribution in an economical manner. This is not at all an easy problem to solve, and much will here again depend on location. The higher the pressure at which power can be distributed, the greater the economy in first cost of construction and in subsequent operation ; but there are two serious drawbacks to high potential,—first, increased liability to derangement in the electrical apparatus ; and second, the difficulty of building and successfully operating motors of small power. Given a certain distance to your center of distribution, you have to strike a balance between interest on cost of large-size copper conductors to reduce the resistance and the extra consumption of fuel required to drive your current over small wires. I am speaking now of a system of constant potential suitable for distribution to consumers in large or small quantities, and not of the new-fangled long-distance alternating-current exploits that require a death's head and cross-bones painted on every pole as a gentle hint to the unwary to keep their own side of the highway. For distribution from a central station within a reasonable area, say half to three-quarters of a mile in any direction, a pressure of 250 volts appears to be most suitable. Motors can be wound for current as small as a quarter of a horse-power. For greater distances, a second system of 500 volts could be utilized with advantage, and at not too heavy expenditure for copper. There are many experiments being made with the view of bringing out a power-distributing system by means of alternating currents, but at present there does not seem to be anything positive in sight that would be better than a constant potential direct-current system at a pressure as low as could be consistently used taking into account distance from source of power, cost of fuel, and interest on cost of copper mains for its supply.

It might be possible in very large installations, or where the ground to be covered is considerable in extent, to establish a system of high-tension mains to distribute an alternating current to central points, and there transform it to a lower potential and utilize it to drive a motor dynamo. This would again produce a direct current at the pressure desired. Except for small powers, it would seem as if the complication introduced in a method of this kind would make the power realized about as expensive as steam on the spot. The position of a pessimist in electrical matters is a somewhat risky one to take at the present day, but it does appear to me that some of the schemes proposed for long-distance power transmission are a trifle outside of the limit of commercial success. The line must be drawn somewhere at a spot where the expense of maintaining costly electric apparatus and the interest on the original expenditure will about counterbalance the cost of fuel and maintenance of a steam engine. It will also be found very much cheaper to locate a factory requiring a large amount of power at the source of power itself than incur a continual expenditure to transmit that power to a distance. As an instance, the elaborate scheme of water power which is now in course of evolution at Niagara Falls may be cited. The American scheme, however, has crystallized into action, and large works are already undertaken. The primary object is to locate consumers at the power, but incidentally it

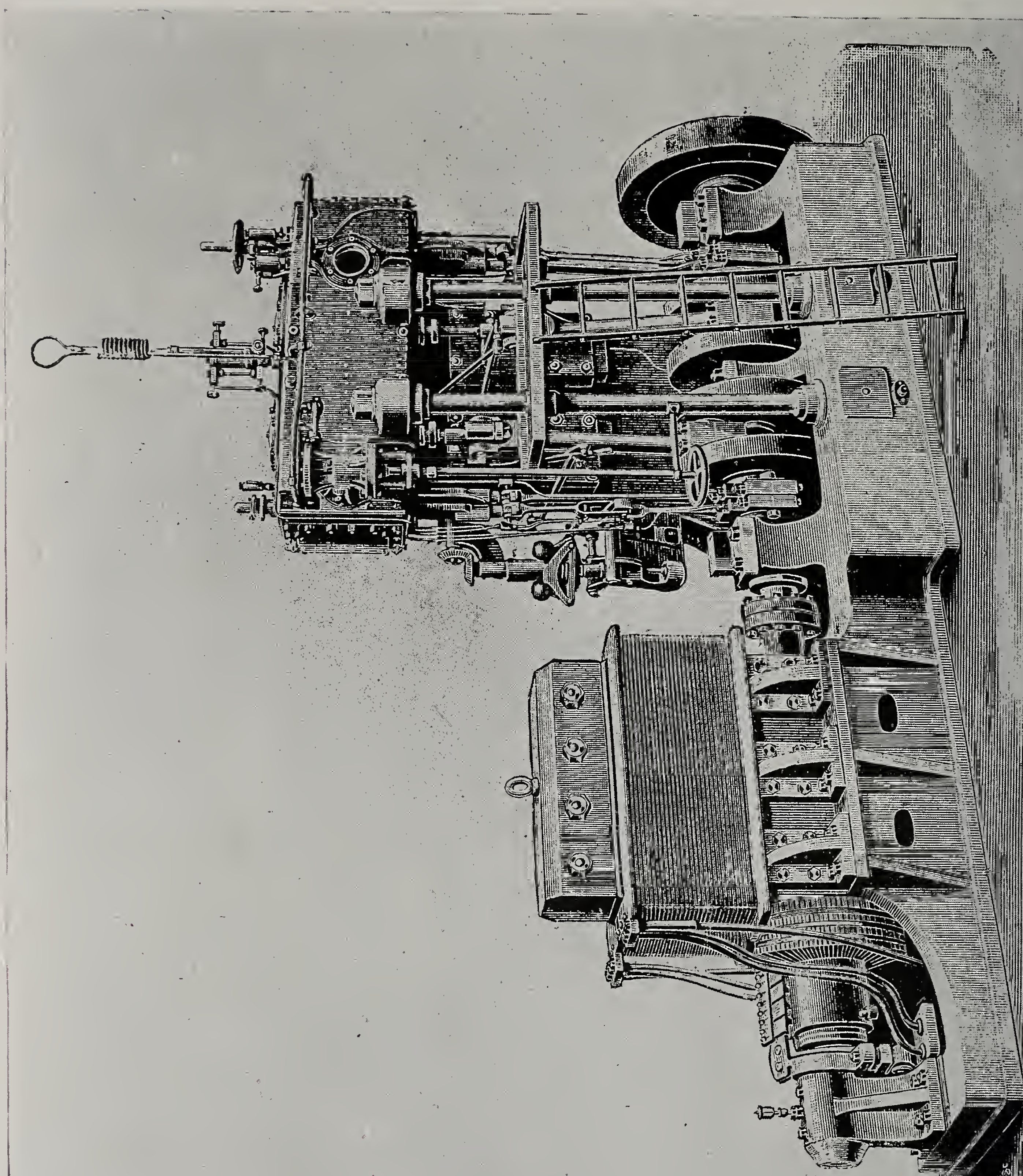
is proposed to transmit a large quantity to the city of Buffalo. Time will show to what extent this may be commercially feasible ; but when the complicated nature of the operation and its cost are considered, there is room for a pretty large-size note of interrogation.

First, we have the proportion of the cost of the water power to begin with, royalties, cost of rock excavation, cost and maintenance of turbine wheels, and attendance. The electrical outfit must be first low-tension dynamos producing alternating current, then transformers to raise the pressure sufficiently high to overcome the twenty miles and more of conductors to the city ; the cost of maintenance, and, above all, the protection of this twenty miles of line ; then again transformers to reduce the pressure to a manageable point ; low-tension, alternating-current motors to convert the current again into power, and finally the cost of its distribution. This expenditure will have to compete with coal at a cost for steam purposes of from a dollar to a dollar and a half per ton. Wonderful things have been done by means of electricity, and this enterprise may be successfully accomplished,—financially I mean. Its practicability from a scientific standpoint has been already demonstrated.

There are locations, however, in our own country (a country where a paternal government is doing its best, according to its light, to further the interests of its people by imposing a duty on fuel), and these places are at such a distance from the source of supply that freight is very costly. Here, if anywhere, will the cost of long-distance power plants and their existence be justified. But the distance must not be too great, or the maintenance of the insulation of the conductors and transformers will become a difficult task as an everyday business operation. Sufficient has been accomplished experimentally ; it only remains for it to attain permanent success. I remember the time, and not so very many years ago, when we considered it a big thing to operate a dynamo in one room and arc lights from it in the next. In those crude and early days it was often necessary for the operator to have his eyes on both of them at the same time. Now arc-light circuits of twenty miles in length are not uncommon. It may be feasible in the near future to carry high-tension secondary currents for long distances in grounded tubes containing oil, and connected to transformers in metal vessels also containing oil, and so protected as to preclude the possibility of accident from contact with them. Probably after a system of this kind is perfected and installed, it will be a fine thing, but it will be more or less risky to the experimenters before the perfect system is reached. I have often thought that a cheap and effective motor power might be devised from the repeated detonation of small quantities of high-class explosives, in situations where the power generated would do the most good,—say behind a piston, as gas is exploded in the cylinder of a gas engine. The difficulty would appear to be in separating at each stroke a minute quantity of explosive without making injurious connection with the whole stock in hand. It might be made successful, but at the expense of several relays of inventors.

Elaborating these high-tension systems may have a similar effect on the available stock of electricians at the outset, but I have no doubt before very long we shall become accustomed to much higher potential in electrical matters than we now have any idea of. Now I remember when eight lights was the average size of an arc-light dynamo, and a twelve-lighter was a monster, and shall not readily forget when, after much consultation, it was decided to build a sixteen-lighter, with what amount of respect for its power we approached the task. When it was completed it was a creation to stand off from and admire at a distance. It was merely a repetition of history. At one time a speed of ten miles an hour on the railway was considered simply as flying in the face of Divine Providence. It is unnecessary to state what the limit of prudence in this respect is considered to be now. This brings us to another development of electricity as a power agent, and that is the proposed electric railroad projected between Chicago and St. Louis. We have very little information as to the methods to be adopted or the volt-

ages to be employed. We are told, however, that the speed is to be 100 miles an hour, and that the line is to be perfectly straight. It will be necessary. If the projectors had said further that it is to be fenced in with boiler plate, it might, to some extent, relieve the feelings of the farmers along the right of way. We are to have some information on the possibilities of electric railroading a little later, so I must not anticipate. The possibilities and probabilities are rather wide apart at present. The electric tramway fills the bill to perfection for the city and suburban passenger traffic ; but you must admit when you see a steam locomotive handle a freight train a quarter of a mile long or so that the electric motor has a fairly hard row to hoe before it will take possession of a trunk line of railroad.



MARSHALL ENGINE COUPLED TO SIEMENS DYNAMO.

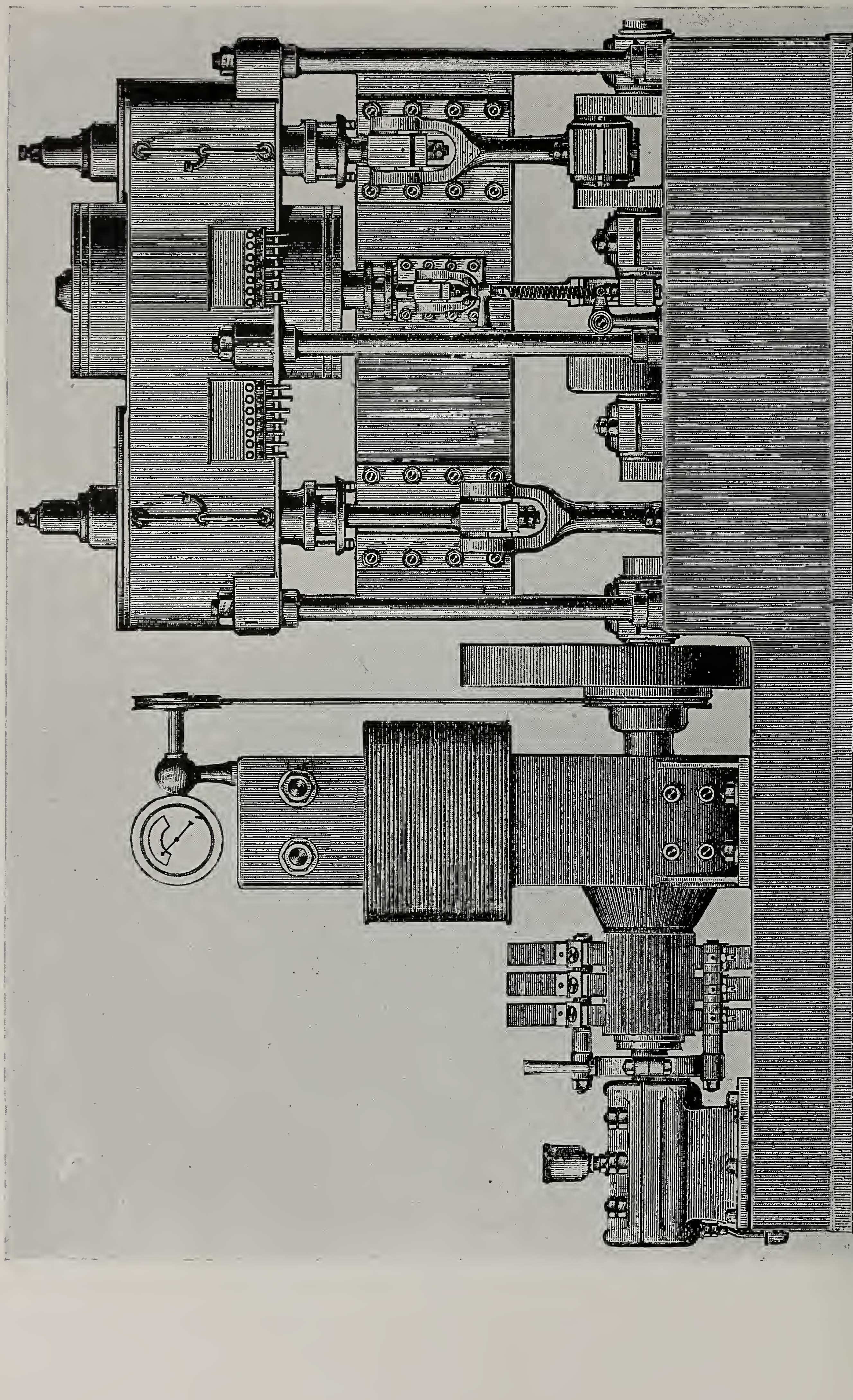
DIRECT-CONNECTED ENGINES.—III.

By Charles H. Werner.

THE Edison Spanish Colonial Light Company have recently put direct-coupled electric plants in the steamships *Ciudad Condal* and *Habana* of the Compania Trasatlantica Espanola. These plants, as illustrated, consist of an "Ideal" 6 x 6 inch engine mounted on the same bedplate with an Edison multipolar machine of sixty-five volts and fifty amperes. The connection between engine and dynamo is made by means of a Brotherhood coupling. These engines were built by the Harrisburg Foundry and Machine Works, of Harrisburg, Pa.

A new high-speed engine has recently been put upon the market by the American Engine Company, of Bound Brook, N. J. Externally it is a simple cylinder resembling a rotary engine. It is not of this type, and yet it has no dead centers, no point at which the steam does not exert the same power on the piston and crank shaft as at any other point, and it takes steam and exhausts four times at each revolution. It may be run up to 1000 or more revolutions per minute, and yet be perfectly automatically governed, and it is claimed governed, too, so perfectly that no flywheel is needed, even when performing a service of the most variable character. The acknowledged purpose of the inventor of this engine was to get an engine that should attain a much higher speed than has ever been attained by high-speed engines, with a greater economy in the use of steam, as well as less mechanical friction. The result of his experiments is the engine herewith illustrated. In the engraving, which shows the outer parts of the engine in transparency and the working parts in full lines, 1 is the bedplate, 2 the cylinder, 3 the cylinder head, 4 the piston, 5 and 6 partition blades, 18 follower pin, 48 spherical bushing, 53 crank disk, 64 stuffing box, 67 pulley, *A* steam chest, *B* exhaust chest, *C* live-steam pipe, and *D* the exhaust pipe.

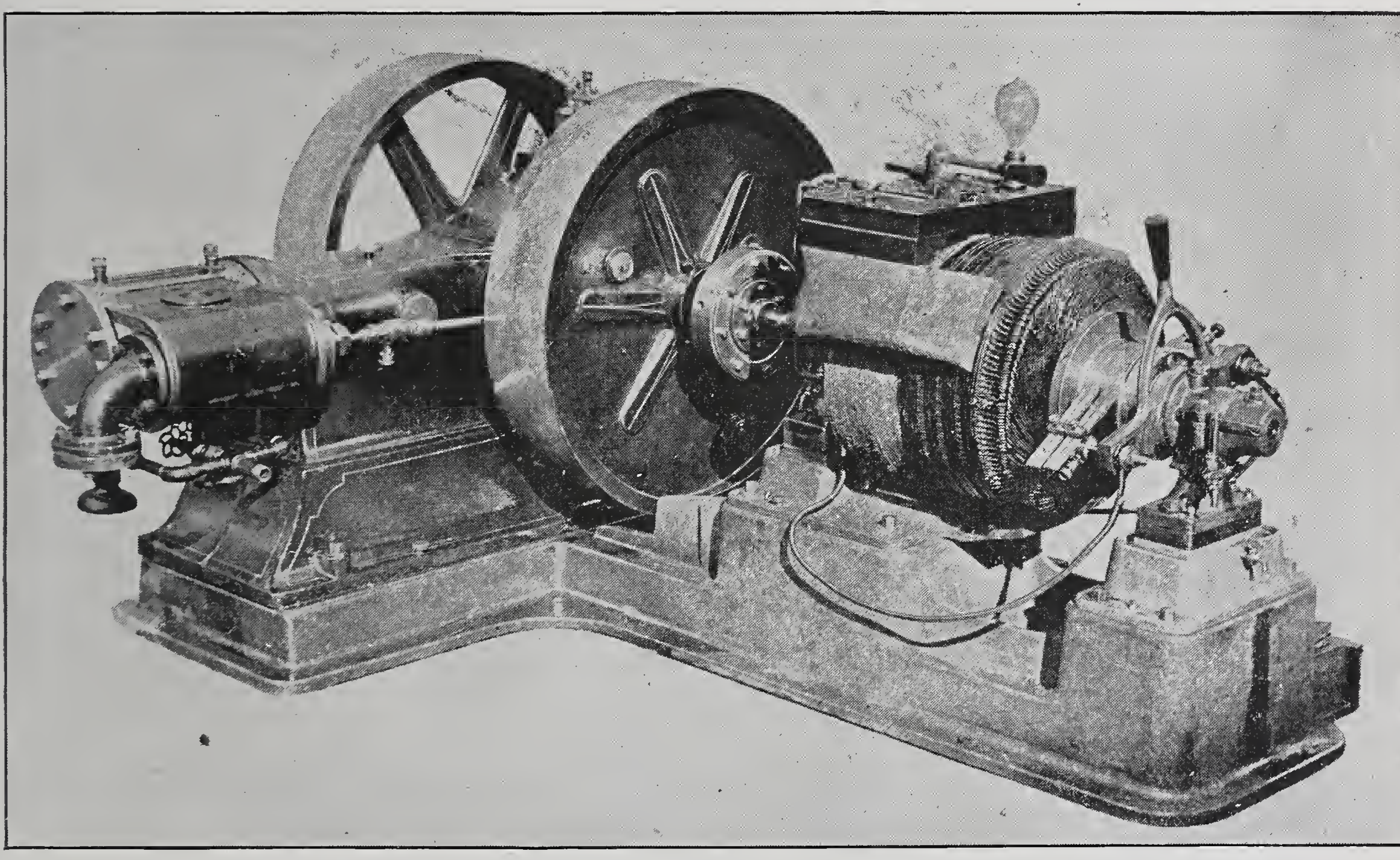
The cylinder is bolted to the bed, and projects into the steam chest, which gives it a live-steam jacket, outside of which is a cast-iron jacket, which prevents all radiation. There is a circular opening in cylinder through which projects the piston stem *F*. This opening admits steam against the back of piston, its area being so proportioned as to balance the pressure of steam in the compartments at the face of the piston, thereby preventing friction between the piston and cylinder. The space between the piston and cylinder head is divided into four compartments by partition blades. These blades have a pivot connection with the cylinder head, which allows them to accommodate the movements of the piston. The sides of the blades radiate from the center of motion, and the wear between them and their bearings against the piston is taken up automatically by a spring advancing them toward the follower pin. The latter is hollow, and connects the exhaust chest with the valve chamber in the piston, and also furnishes an abutment for packing strips in the ends of the blades. The crank disk and shaft are supported in frictionless roller bearings, as shown in the illustrations. The main and cut-off valves are located inside the piston, and bear against the follower pin, describing a circle at each revolution, together with the piston stem and crank disk, about the axis of the shaft, the radius of the circle decreasing toward the follower pin. The main valve also turns on its axis, being rigidly attached to the spherical bushing, which is connected to the crank disk by a screw. This valve controls the admission of steam to the steam compartments, also the exhaust. The cut-off valve controls the time of closing the steam port. Its stem extends



COMBINED PLANT FOR SHIP ELECTRIC LIGHTING, BUILT BY ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE.

through the main-valve stem to the back of the crank disk, where it connects with the governor. The engine is compact and self-contained, and is claimed to be particularly suitable for electric-light work, driving the dynamo direct from the engine at any velocity desired up to 2000 revolutions per minute, and under perfect regulation as regards speed.

Upon another page is presented a view, taken from the London *Electrical Review*, of a Marshall engine combined with a Siemens dynamo. The engine is side are of the automatic type, the main valve is of phosphor-bronze, and the expansion valve is of cast iron, the same class as that of the cylinder, and is fitted with springs at the back. On the low-pressure side Meyer's expansion gear is applied, enabling the admission of steam to the low-pressure piston to be varied by hand. Both the main valve and the expansion plates are of cast iron. The starting valve is of the Wing type, fitted with suitable valve and seat, both of gun metal, and having a long spindle with outside screw and

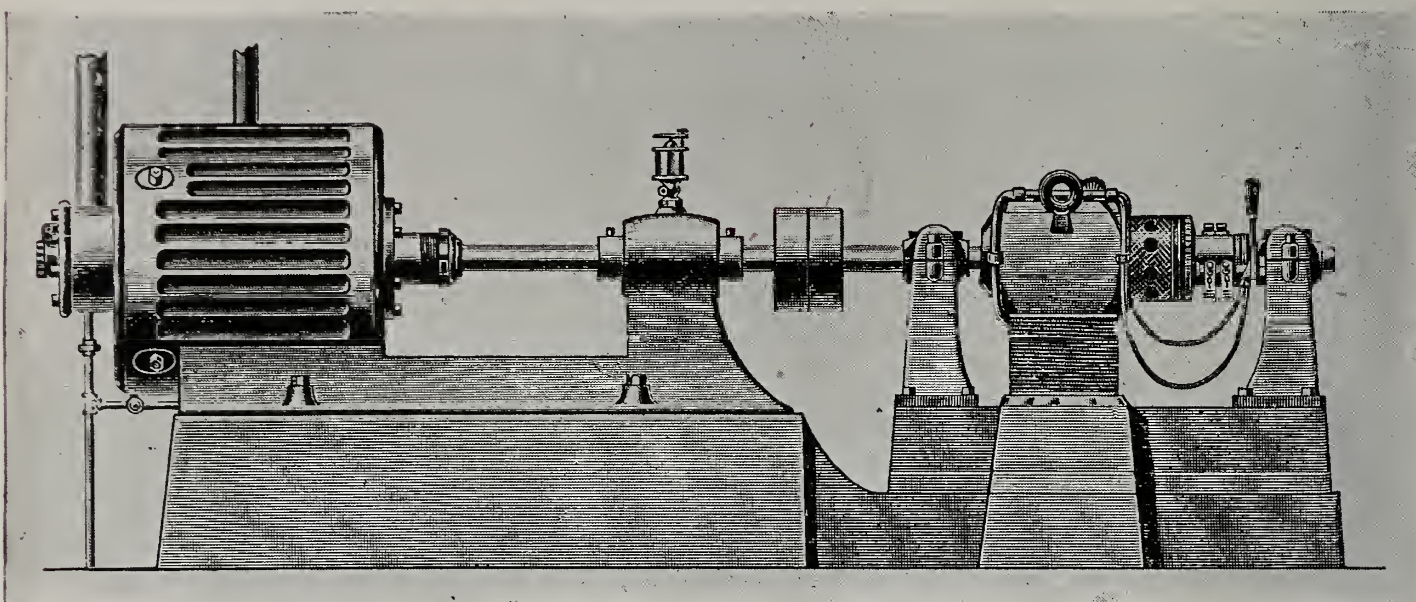


"IDEAL" ENGINE, MANUFACTURED BY HARRISBURG FOUNDRY AND MACHINE WORKS, CONNECTED WITH BROTHERHOOD COUPLING TO EDISON MULTIPOLAR DYNAMO.

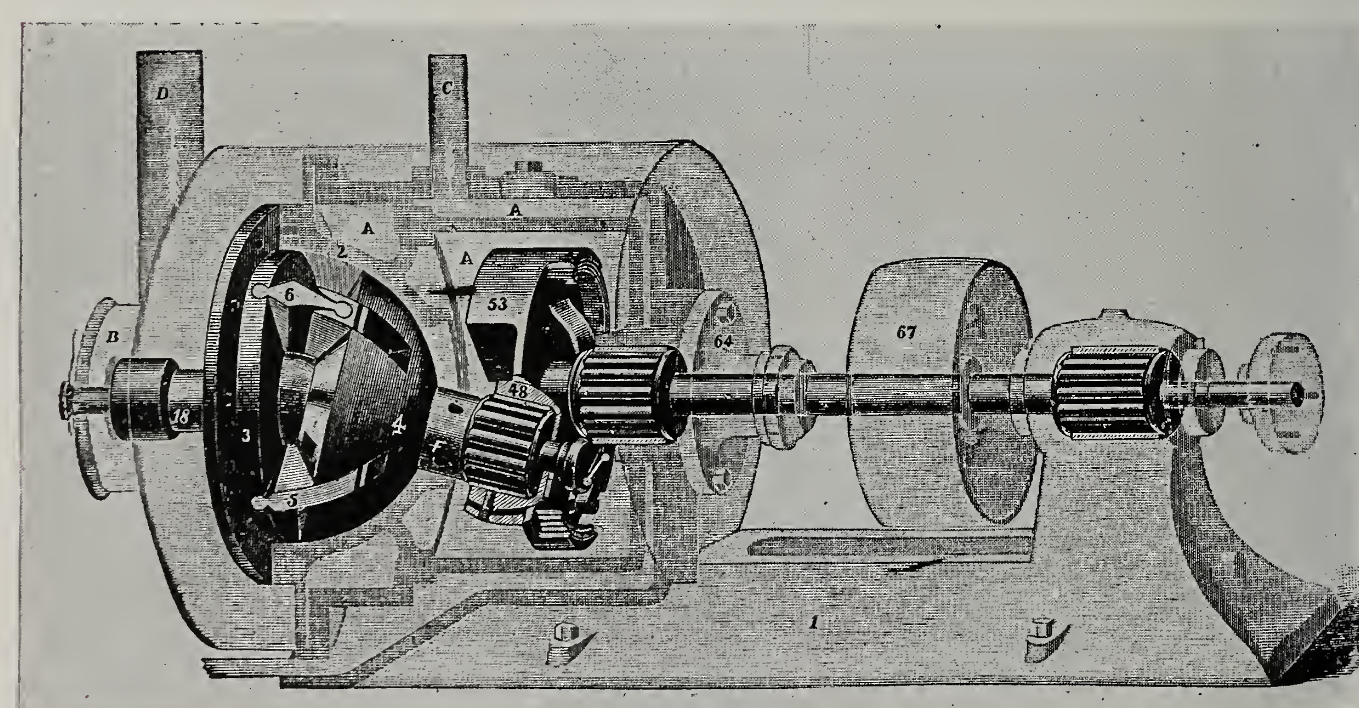
a compound independent vertical, with patent automatic expansion-valve gear. It is mounted on a cast-iron bedplate, on which the dynamo is fixed. The cylinders are supported by a strong hollow standard at the back, firmly secured to the base, and by two massive wrought-iron stay-rods in front. The standard carries the governor stand and the slide-bars. Both cylinders are steam-jacketed, being fed from the outside and drained by means of a steam trap. The slide valves on the high-pressure hand-wheel, which is brought within easy reach of the engine-room floor. The casing is provided with a branch to feed the steam jacket, admitting steam therein before the valve is opened for starting the engine, thus enabling the cylinders to be well warmed before running. The low-pressure cylinder is provided with a smaller valve for admitting high-pressure steam to the low-pressure piston to facilitate starting under a heavy load.

Messrs. Kummer & Company, of

Dresden, have for some years paid great attention to engines and dynamos specially designed for ship-lighting. The engraving printed herewith, taken from the *Electrical Review*, shows one of Messrs. Kummer's large dynamos driven by a compound engine at a speed of 400 revolutions per minute, which gives a current of 330 amperes at 120 volts. The armature is Gramme wound with 320 turns of wire connected up to a commutator with 160 segments. The four magnet cores are cast in one with the engine bedplate, the yoke being formed by a heavy circular block at one end of the latter. To these magnet cores are attached by steel screws pole pieces tapered toward the end, as shown. A cast-iron bridge bracket lying diagonally and attached to two of the pole pieces carries the outside bearing. The engine cylinders are nine and one-half and fifteen inches diameter respectively, and both are



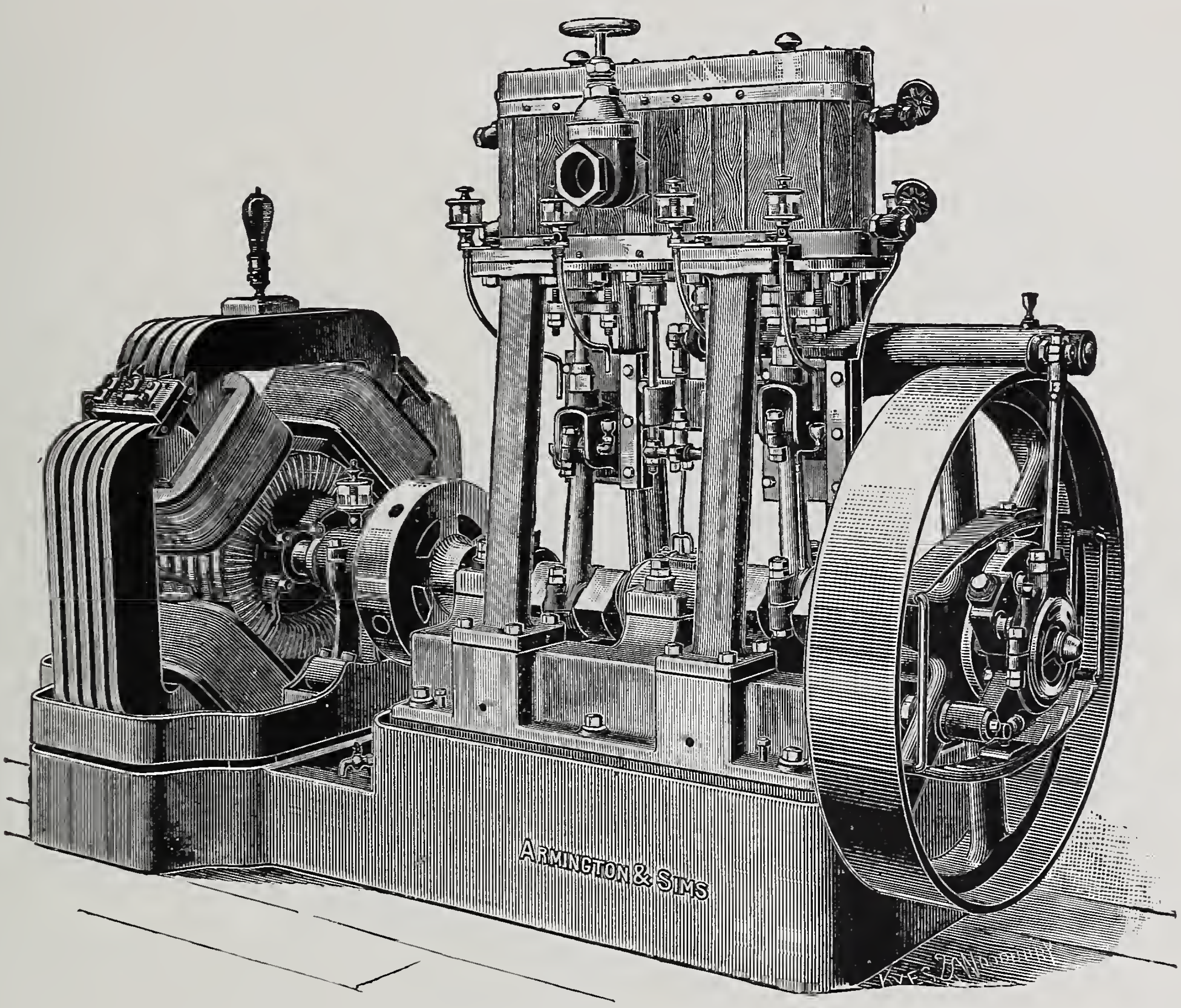
ENGINE MANUFACTURED BY AMERICAN ENGINE COMPANY, BOUND BROOK, N. J., COUPLED TO THOMSON-HOUSTON DYNAMO.



DETAILS OF ENGINE MANUFACTURED BY AMERICAN ENGINE COMPANY, BOUND BROOK, N. J.

steam-jacketed. The stroke is nine inches, and the piston speed, therefore, ten feet per second. The engine is designed to work with a pressure of 120 pounds, and when normally loaded both cylinders do about equal work. The cylinders are cast in one with the slides, and the superstructure is supported by four wrought-iron columns. The engine proper has four bearings and the dynamo one. The low-pressure eccentric is keyed on the shaft between the two cylinders, while the high-pressure one is influenced directly by a governor cased in on the right-hand end of the shaft. There is also presented an illustration of a combined plant, built by the same firm, which is the type used by the imperial German navy, the output for all the machines on their ships of war being 12,000 watts at a speed of 450 revolutions per minute.

Amongst the engines exhibited at the recent Crystal Palace exhibition in London were several by Messrs. Charlesworth, Hall & Co., some of which are illustrated herewith. One is an open-frame, single-crank, compound engine, the two cylinders being superposed. The piston rod is common to both cylinders, which are respectively of four and five and one-half inches diameter, with a stroke of four and three-quarter inches. A Pickering governor is employed, and the engine is coupled direct to a Hall dynamo, which it drives at 540 revolutions per minute. At this speed the machine gives seventy-five amperes at sixty-five volts. The frame consists of steel pillars fastened by nuts under the bedplates, and carrying a casting which is fitted with crosshead guides. The cylinders are provided with piston valves ground in, and the pistons are of aluminum steel fitted with cast-iron rings. The engine is single-acting.

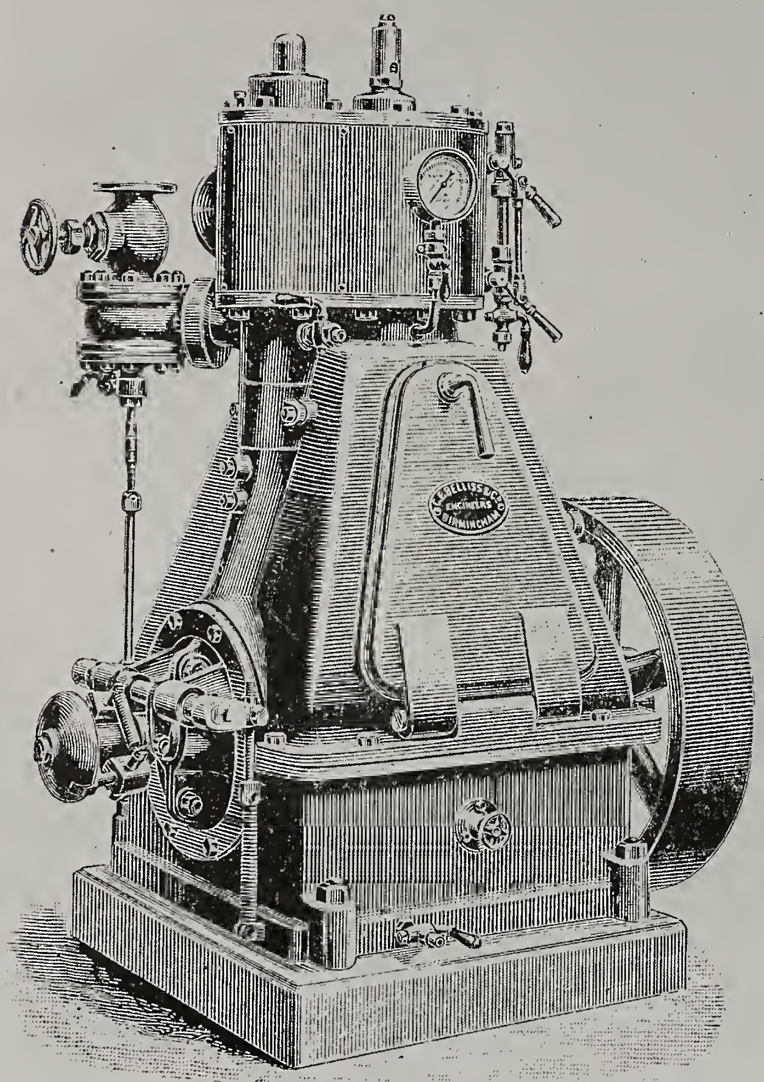


SPECIAL DOUBLE ENGINE, BUILT BY THE ARMINGTON & SIMS ENGINE COMPANY, AS FURNISHED THE U. S. NAVY DEPARTMENT.

The accompanying sectional and plan

views, taken from *The Engineer*, show the arrangement of a similar but larger engine with dynamo for ship-lighting. The cylinders are six and one-half and nine inches respectively, with an eight-inch stroke. The engine, like the foregoing, is single crank, and runs at 380 revolutions per minute. The sectional engraving shows the arrangement of the piston valves, which like the pistons are on one rod, with a metallic packing between the two steam chests. A very long stuffing box is used for the piston rod, and the gland is screwed up by an exterior nut, which prevents the uneven screwing up common with ordinary glands. The engine is coupled direct to a Hall dynamo, having a Gramme armature twelve inches in diameter, fourteen inches long, and built up with 160 copper bars.

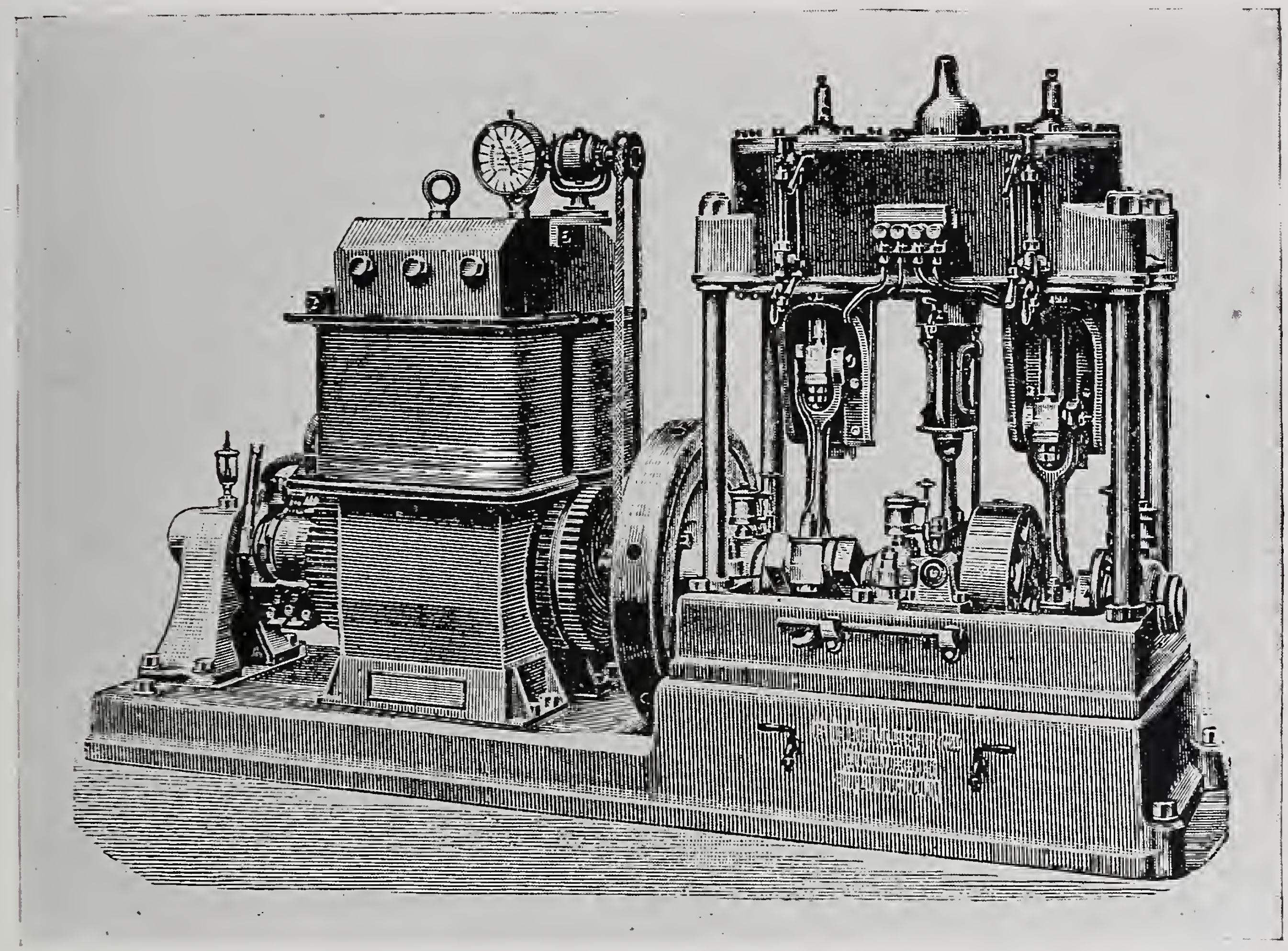
A combined engine and dynamo for ship-lighting purposes has lately been brought out by Messrs. Laurence, Scott & Co., of Norwich, England. The engines are specially designed to work with a high steam pressure, and at a high speed, being perfectly balanced. All wearing parts are large, and the engines are fitted with Pickering governors, and are capable of running continuously at high speeds, the lubricating arrangements being specially designed with this view. The iron disks forming the armature core are stamped with a hexagon hole, and driven tightly with insulating strips on to a hexagon shaft, the conductors being embedded in the slots milled in the circumference of the armature. A sufficiently large margin is allowed in the output of both engines and dynamos, so that the dynamos will



BUILT BY C. E. BELLISS & CO., BIRMINGHAM, ENG.

do their full load in very hot engine rooms, and the engines will run with low steam pressures. The bedplate is very solid, and the dynamo is arranged to give a low center for the engine crank shaft.

Messrs. Johnson & Phillips, of Charlton, Kent, England, build a central station dynamo coupled with a triple-expansion engine by Messrs. Davey, Paxman & Co., of Colchester, England. The engine, of which an illustration is shown, has cylinders of twelve inches, eighteen two feet eight inches above floor level. Steam can be admitted directly into the intermediate steam chest for the purpose of starting the engine in any position. The governor is of Paxman's improved design, extremely sensitive, keeping the engine under excellent control; when the governor lifts it pulls over a link bringing the short throw eccentric into action, with expansion-valve spindle, and cuts off steam earlier, keeping the speed constant. The fly-wheel is six feet in diameter.

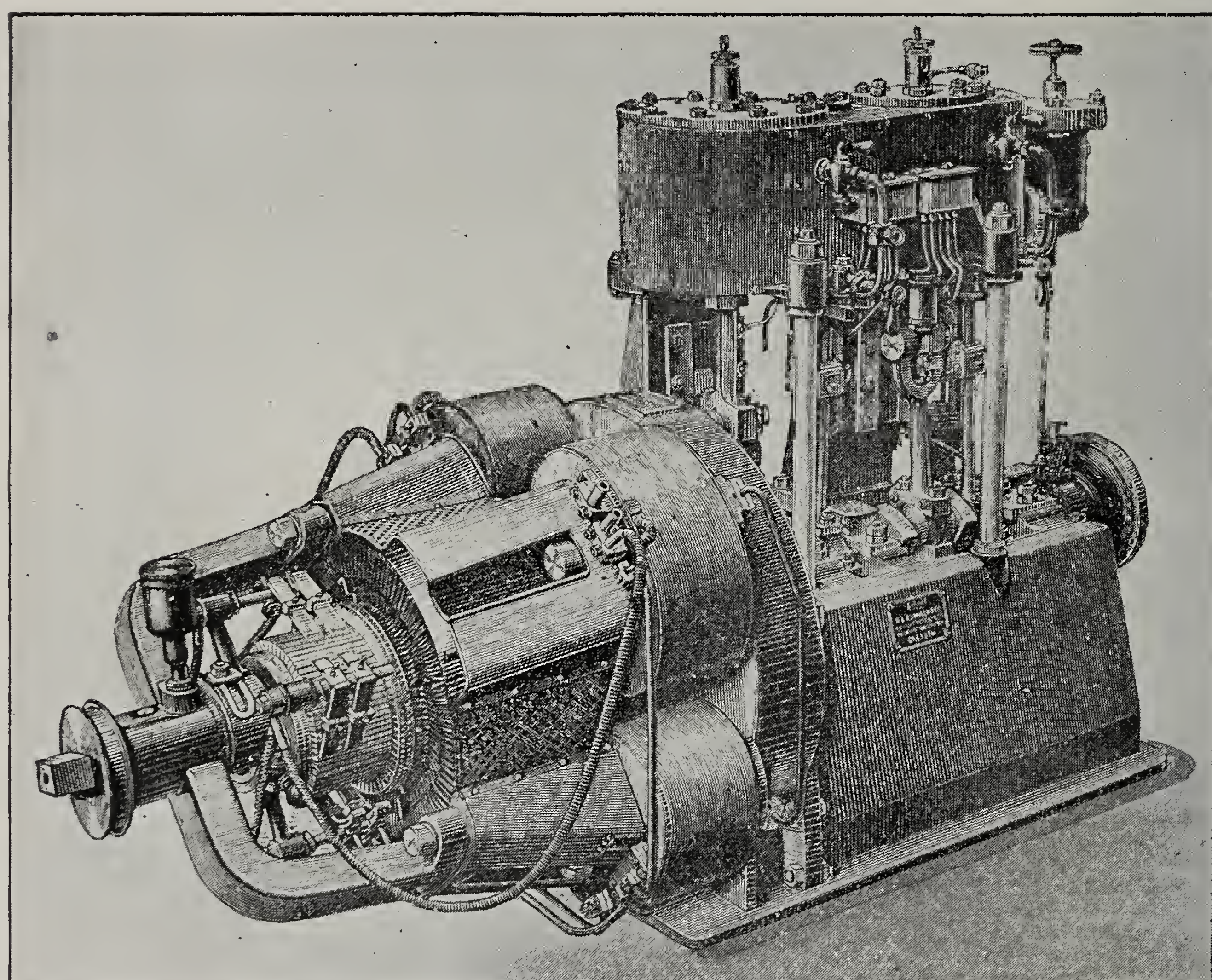


BUILT BY C. E. BELLISS & CO., BIRMINGHAM, ENG.

and three-quarter inches, and thirty inches diameter respectively, with a stroke of eighteen inches. It is designed for an indicated horse-power of 350 at 140 revolutions (or 320 indicated horse-power at 130 revolutions), and 160 pounds steam pressure. The floor space, including platform, is ten feet six inches by six feet nine inches, and from the floor line to top of cylinders is eleven feet, the extreme height to top of sight-feed lubricators being three feet two inches more; the platform is

In another illustration is shown a combined engine and dynamo built at the Portsmouth, England, Dockyard for H. M. S. *Rupert.* The work has been carried out to the ordinary Admiralty specifications, which require that the engines shall be capable of working the dynamo at full load with 100 pounds boiler pressure, the engines working non-condensing. The governor must be capable of adjustment whilst the engine is running, and on removal of the whole load the speed must not increase

more than five per cent. above the normal. The dynamo to comply with the specifications must be of the direct-current, self-regulating type, and must give 400 amperes at eighty volts when running at normal speed, which is fixed at 400 revolutions per minute for special engines and at 300 revolutions per minute for open or double-acting engines. The electromotive force must be maintained constant at all loads from ten to sure per square inch the plant showed an average steam consumption of thirty-eight pounds per electrical horse-power in a six-hour trial, throughout which the electromotive force at the brushes was steadily maintained at eighty volts. The revolutions varied from 330 with no load to 324 per minute at full load, and on suddenly opening the circuit they increased momentarily to 350 per minute. The indicated horse-power was

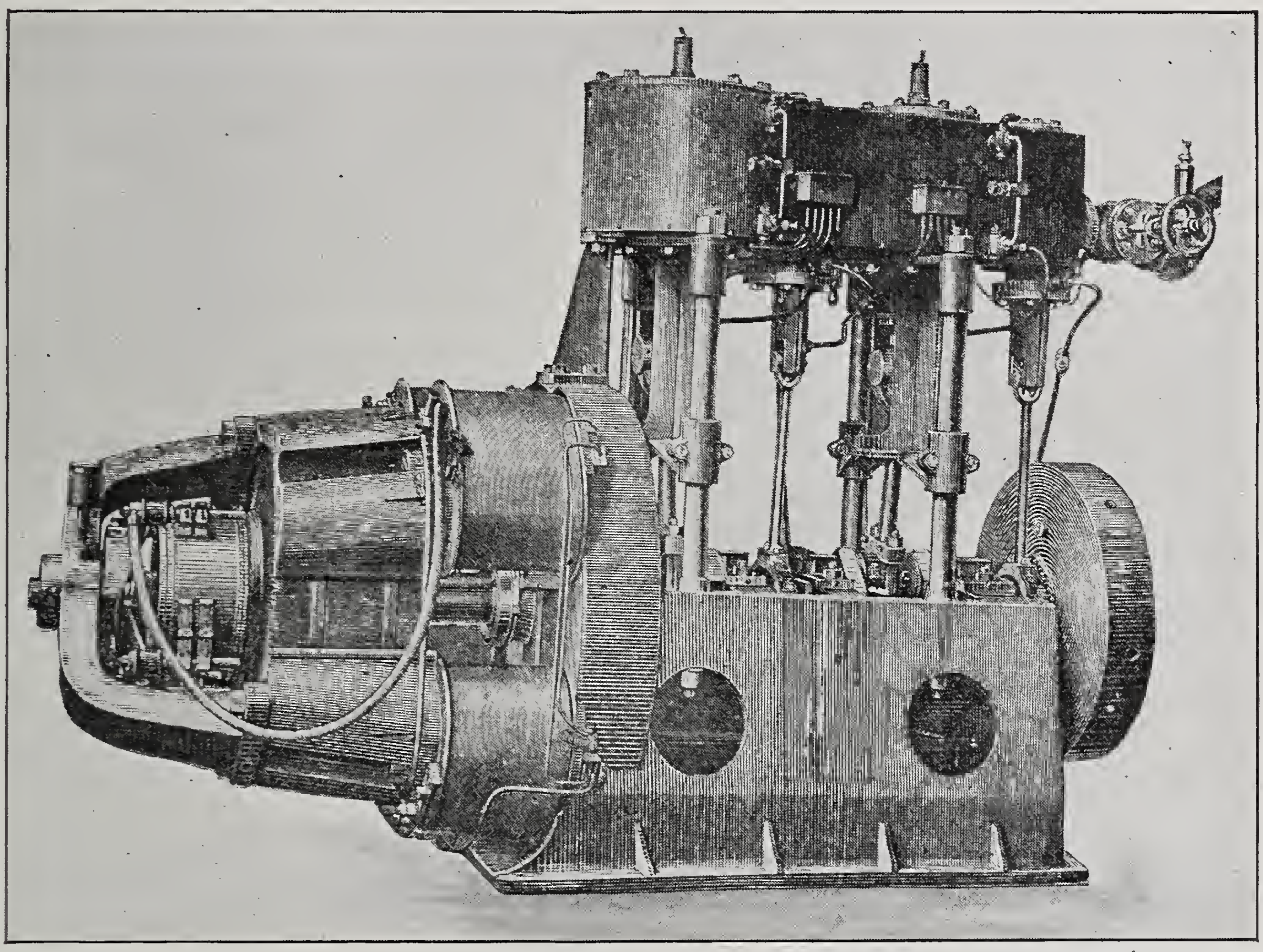


ENGINE AND DYNAMO DESIGNED FOR SHIP-LIGHTING, BUILT BY KUMMER & CO., DRESDEN.

400 amperes. The present plant has been built to conform very closely to the above specification. The engines are of the ordinary compound tandem type, with two high-pressure and two low-pressure cylinders, the diameters of these being six inches and eleven and one-half inches respectively, and the stroke is six inches. The dynamo is of Messrs. Latimer Clark, Muirhead & Co.'s Westminster type. When tried with steam at ninety pounds pres- 56.01 and the electrical 42.89, giving an efficiency of conversion equal to 76.6 per cent. The total weight of engine and dynamo complete is about five and one-half tons, and the floor space occupied is ten feet two and one-half inches by three feet one inch, the maximum height above the floor being six feet seven and one-half inches. The engraving of this plant is taken from *Engineering*.

On the continent of Europe, although

there is no standard central station practice, yet that initiated by Messrs. Siemens & Halske for the great stations at Berlin has been very largely adopted, and has been imitated by several other large continental firms. In this case the units of supply consist of slow-running steam engines of from 300 to 500 horse-power driving large slow-speed dynamos mounted direct on an extension of the crank shaft of the engine. These slow-running engines and dynamos probably occupy four times the space and cost twice as much as the quicker running steam dynamos of equal power used in English practice. One probable cause why high-speed steam dynamos have not found much favor on the continent of Europe is that their use was initiated by Edison in the original "Jumbo" type of steam dynamo sent to England and to various parts of the continent in 1882. The simple type of high-speed engine then used was not an economical one, and the continental engineers compared its extravagant consumption of steam with the highly economical results they obtained from the slow-running engines made by Van der Kirchove at Ghent, Kühn in Germany, and Sulzer in Switzerland, and other makers of celebrity. The only other high-speed engines which have found their way to the continent were a few of the Westinghouse type, and some of the earlier engines made by Messrs. Willans; but none of these seemed to meet the ideas of the continental engineers. The dynamo designers had, therefore, to adapt the design of their machines to the requirements of the engine-builders, and the large ring armatures introduced by Messrs. Siemens and used in the Markgrafenstrasse central station in Berlin were the first examples of the kind. These plants, although extremely costly compared with their output, commanded admiration, and established a type which could safely be copied.



ENGINE AND DYNAMO DESIGNED FOR SHIP-LIGHTING, BUILT BY KUMMER & CO., DRESDEN.

(To be continued.)

MECHANICAL METHODS OF SECURING DRY STEAM.

By Professor R. C. Carpenter.

THE presence of a large amount of water in the steam for a steam engine is often the cause of serious breakages to the engine, besides detracting from the economy of its operation. The amount of water which may be taken up and held in suspension by the steam depends upon various circumstances, of which the most important is the velocity with which it leaves the surface of the water from which it is generated. In the work, "Steam," issued by the Babcock & Wilcox Boiler Co., the statement is made that a current of steam with a velocity as low as 1 foot per second will carry with it a globule of water $\frac{1}{1000}$ of an inch in diameter; and if steam rises from the surface of the water faster than 2 feet 6 inches to 3 feet per second, it will carry with it considerable water in the form of fine spray.

The carrying of water from the boiler with the steam is termed "priming," and may be caused by impure water, improper proportions of the boiler, too much water, or very heavy firing. Priming may occur uniformly, in which case the steam is loaded with fine drops of water in the form of mist or spray; or it may occur at irregular intervals, when large quantities of water may be thrown into the steam-pipe by violent ebullition. During the passage of steam from the boiler to the engine more or less condensation takes place, so that the entrained water in the steam may be, in part, due to priming, and in part to condensation. While, under some circumstances, the latter quantity may be of considerable amount, it is not likely to be a source of disaster to the engine.

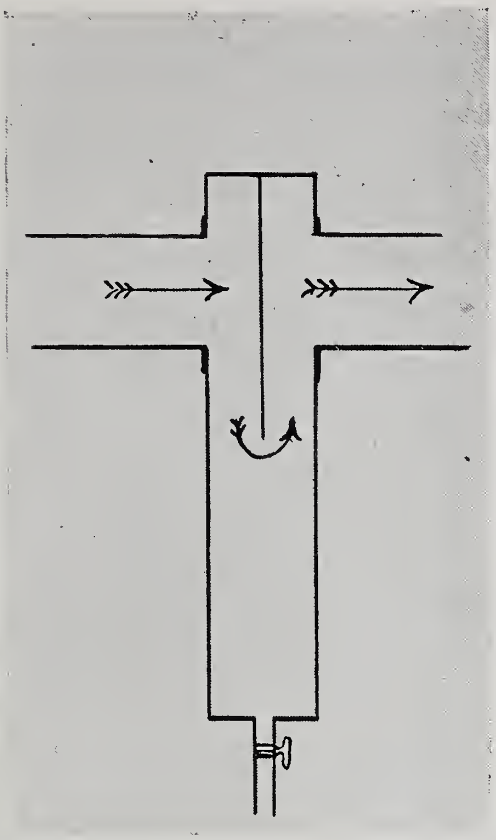
The amount of entrained water is usually expressed in percentage of weight. As water is very much heavier than steam, a large percentage by weight is a very small one by volume. Thus, at 150 pounds steam pressure a cubic foot of steam weighs about one-third of a pound; a cubic foot of water, at the same temperature, weighs a little over 56 pounds; so that an equal weight of steam occupies 168 times as much space as the water. Thus, if steam of 150 pounds pressure were condensed, it would only occupy about six-tenths of 1 per cent. of its former volume.

The following table shows the relation that percentage of moisture by weight bears to percentage by volume, and makes it easy to comprehend why it is possible for steam to carry large percentages of water by weight:

Percentage of Water by Weight.	Corresponding Percentage of Water by Volume.		
	150 pounds absolute pressure.	100 pounds absolute pressure.	25 pounds absolute pressure.
10.0	0.059	0.040	0.010
20.0	0.119	0 081	0 021
30.0	0.178	0.122	0 032
40 0	0.238	0.162	0.043
50.0	0.297	0.217	0.053
60.0	0.357	0 242	0.065
70 0	0.417	0.285	0.075
80.0	0.476	0.325	0.086
90.0	0.536	0.366	0.097
100.0	0.597	0 406	0.107

The amount of priming varies greatly in different steam plants. The experiments of M. Hirn, at Mülhouse, showed an average of at least 5 per cent.; those of Zeuner, 7½ to 15 per cent.; those of the American Institute, in 1871, with cylindrical tubular boilers, 7.9 per cent.; those at the Centennial Exposition, from 4 to 18.5 per cent.; in test reported in Vol. XII. of "Transactions of Amer.

Soc. Mech. Engineers," of a tubular boiler, by Henthorn, 4.96 to 10.93 per cent.; in tests by the author, 1 to 8 per cent. for tubular boilers, and 1 to 6 per



HAYCRAFT'S SEPARATORS, DESIGNED IN 1830.
PLATE I. FIG. I.

cent. for water-tube boilers. Mr. G. H. Babcock states that steam containing not more than 3 per cent. of water by weight may be termed commercially dry. From this we are to understand that if the amount of water by weight does not exceed 3 per cent., the steam may be used with satisfactory results. The amount of water that may cause disastrous accidents depends largely upon the construction of the engine and the speed at which it is operated. The examination of the heat losses which occur in the passage of steam through a cylinder has shown that if the steam be dry on entering it may contain 60 per cent. of water at cut-off, and 20 to 50 at the end of the stroke, without producing disastrous results. On the other hand, if much water enters with the steam, it is likely to be retained in the clearance spaces until a sufficient amount accumulates to cause an accident,—probably the blowing-out of piston-head or the breaking of piston-rod or of connecting-rod.

The value of dry steam is thoroughly recognized by engineers of high-speed engines, and it is the principal object of this article to point out methods which have been employed, with more or less success, to secure it.

These methods as indicated are :

1. The generation of steam at such low velocities that it shall under all conditions leave the boiler dry.

2. Superheating the steam in the pipes by extraneous means.

3. Separating the entrained water by mechanical methods.

The first method, to be thoroughly practicable, requires very large boiler plants for the power to be generated, and frequently involves a greater outlay for boilers than is warranted by the business to be done. While due consideration should always be given this method, it usually will not be desirable to reduce the evaporation below a certain amount per square foot of heating surface.

The second method, superheating, can hardly be considered a practical one,

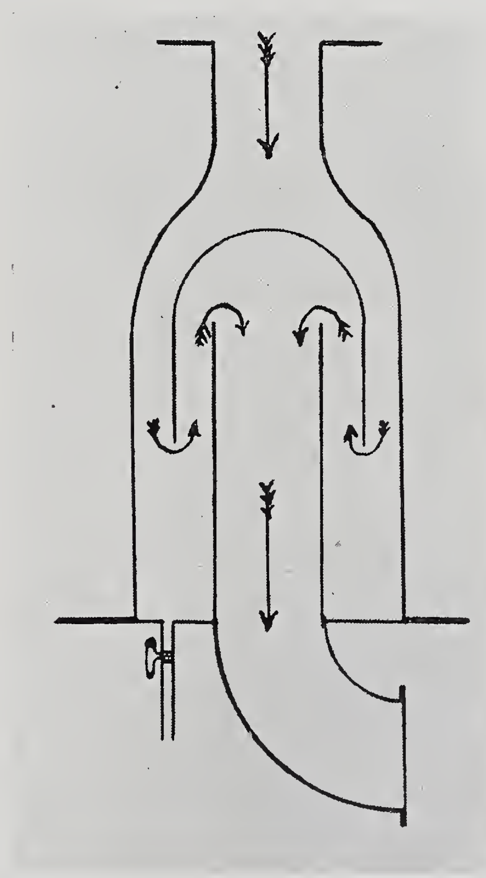


PLATE I. FIG. 2.

since it has been thoroughly tried, and abandoned as dangerous.

The third method, that of removing the water by mechanical means, is the

one of principal practical importance, and has been employed, with more or less success, since the year 1830.

For mechanically removing the en-

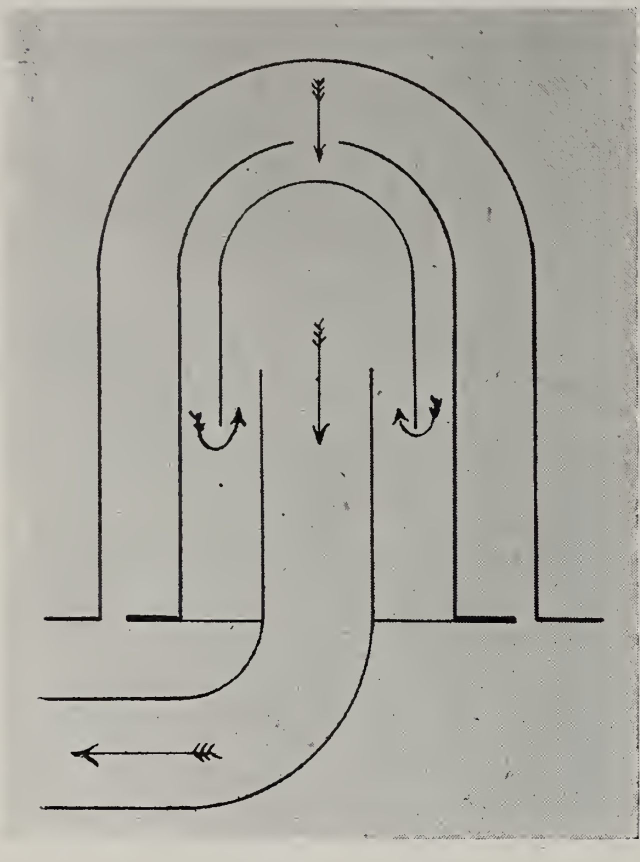


PLATE I. FIG. 3.

trained water two distinct methods have been tried, separately or in combination, viz.: that of reducing the velocity of the current of steam to such an extent that the entrained water will separate from the steam; and secondly, of employing the extra centrifugal force due to the greater weight of the water to throw it into a different channel from that taken by the steam. In the first case, the volume of the steam-pipe is increased; the velocity of the steam flowing through this enlarged portion is reduced, and an opportunity is provided for the heavier particles of water to fall into a position in which they can be drawn off and removed. In the second, the steam is made to make one or more abrupt turns; the heavier particles of water tend to preserve the original direction of motion, and are guided into separate conduits or vessels, from which they may be drawn off. The mechanical arrangements to remove water from the steam are now known as steam-separators, of which the principal, or at least the older, ones are constructed as follows:

The earliest forms that we have been able to find described were devised by Haycraft in 1830, as a result of his investigations, and are shown in Plate 1. Of these forms, Fig. 1 shows a style which is adapted to a straight pipe. The incoming steam is deflected by a diaphragm, to which the water is supposed to adhere, to run along its lower edge, and finally drop to the receptacle below. Fig. 2 is a modification applied to a vertical pipe. Fig. 3 is an application of the same idea to a steam-drum, steam and water rising to the top. Dry steam is supposed to be drawn off after the water has been thrown out by deflecting plates and change of direction of the steam. Fig. 4 is an application to a horizontal pipe, the steam being made to take an abrupt bend of 180 degrees, the water precipitated to the bottom of the vessel, where it can be drawn off. This latter form is much like several of the commercial separators in use at present.

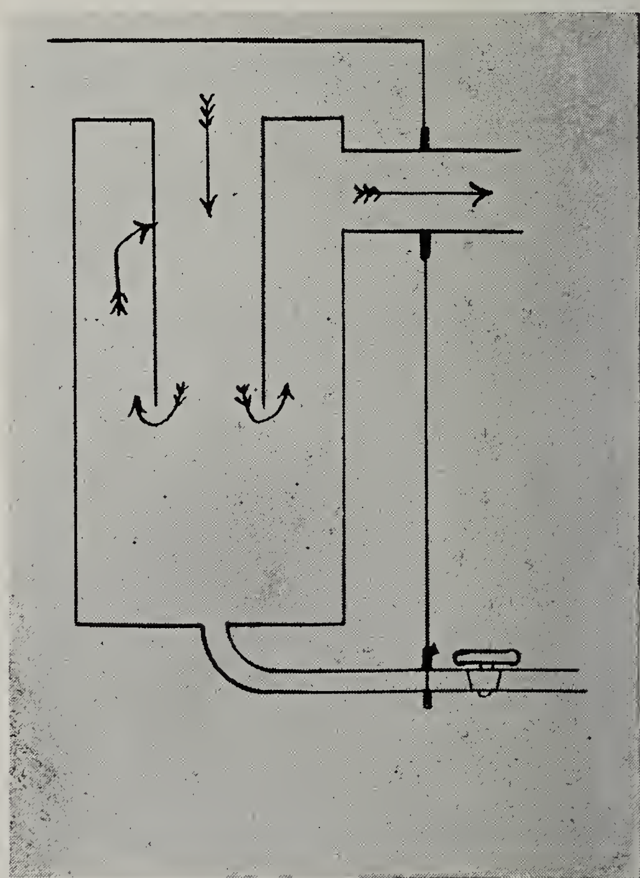


PLATE I. FIG. 4.

Of commercial separators, one of the oldest and best known is the Stratton. As seen in Plate 2, this separator consists of a vertical cylinder with an internal central pipe extending from the top

downwards for one-half the height of the apparatus, leaving an annular space between the two. The steam is admitted at one side, and is then deflected by a

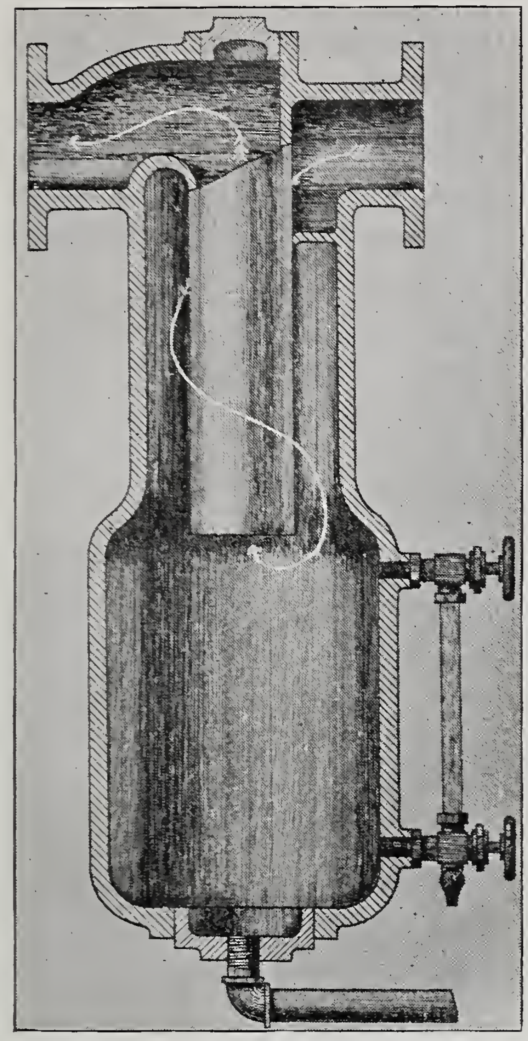


PLATE 2. THE STRATTON SEPARATOR.

curved partition, and thrown tangentially into the annular space at the side near the top of the apparatus. The principle on which it acts may be stated as follows: If a rotative motion is imparted to steam, all the liquid particles it may contain being heavier, tend to move in a tangential direction, and are projected to the outside of the current and to the surface of the vessel. These adhere to the surface, and fall to the bottom. The current of steam maintains a spiral course to the lower end of the internal pipe, then it makes an abrupt bend and enters it on its way to the engine. A water gage-glass is added to the lower part of the separator, so that the amount of water in the separator can be seen, and, if necessary, removed by opening the drip-valve.

The Westinghouse separator is shown as adapted for vertical pipes in Plate 3, the one for horizontal pipes being constructed in a similar manner. The action of this separator is as follows :

The steam and water passes down through the inlet into the separator body at high velocity, the steam-pipe leaving the separator being of the same size as that entering, while the body is much larger. The steam takes a quick turn upwards, but rises slowly through the separator, regaining its normal speed again when it enters the outlet-pipe. The water, being of greater weight, is precipitated downwards, and strikes the perforated diaphragm. Water adheres to this, runs along, drops through the holes into the chamber below, from which it is removed either by means of a drip or by the "steam-loop" to the boiler. The diaphragm is punched with a great many small holes, the burr from punch-

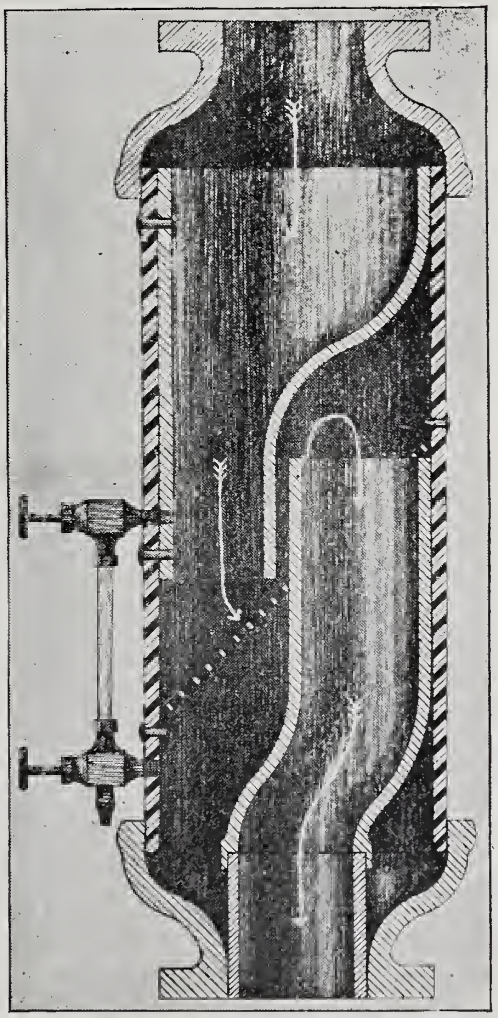


PLATE 3. THE WESTINGHOUSE SEPARATOR.

ing being always on the under side, so that the steam has but little chance to pick up the water again. In this separator the area and velocity of down-

flow is in the ratio of about 4 to 1 to the area and velocity of upflow, so that the water is removed both by action of centrifugal force and by reduction of the velocity.

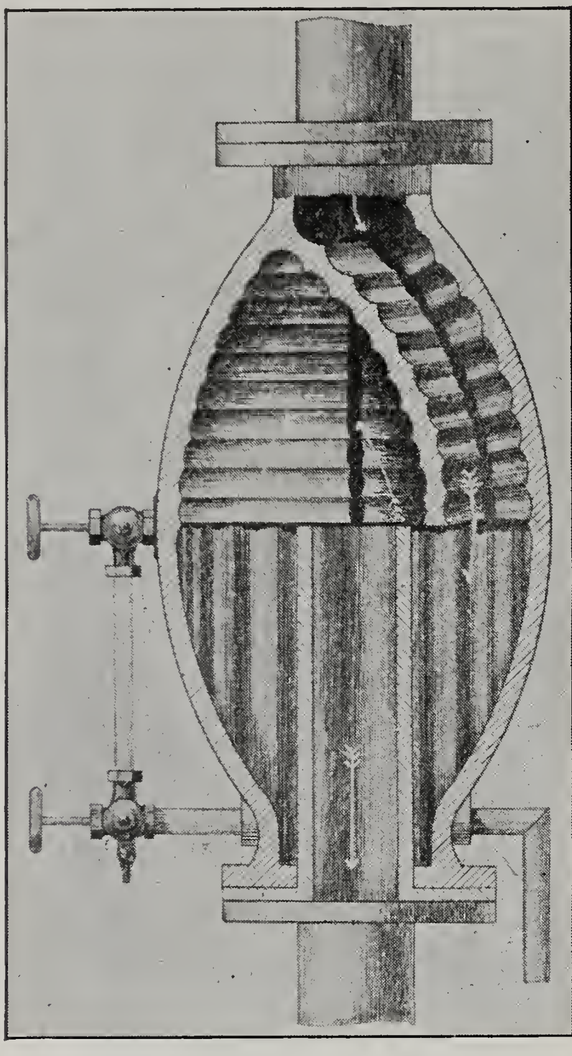


PLATE 4. THE HINE ELIMINATOR.

The Hine eliminator, shown in Plate 4, is also adapted for vertical or horizontal pipes. This form was first used as an eliminator of oil from exhaust-steam. As shown by the drawings, the interior surface is corrugated with a series of horizontal corrugations, which are crossed at intervals by vertical corrugations leading to the lower portion of the vessel. The current of steam, in passing through the deflecting partition, is slightly deflected to one side, so that the water is thrown against the transverse corrugations. After passing into the body of the separator the steam rises slowly, and makes an abrupt bend into the discharge-pipe; the water gravitates to the bottom, and is drawn off by the drip. In this separator the form of the corrugations is such as to retain and provide a channel, out of contact of the body of the steam, for all water thrown by inertia against the side of the separator.

The Curtis separator, shown in Plate 5, is constructed with a series of deflecting plates, through which the ascending stream of steam and water must pass. The steam enters near or at the top, and is deflected downwards by a plate, at considerable velocity, into the main portion of the separator. The current of steam on its passage to the outlet rises with much less velocity and passes a series of V-shaped deflecting plates. The increased momentum of the particles of water causes them to strike the sides of the separator and of the deflecting plates, whence they are conducted

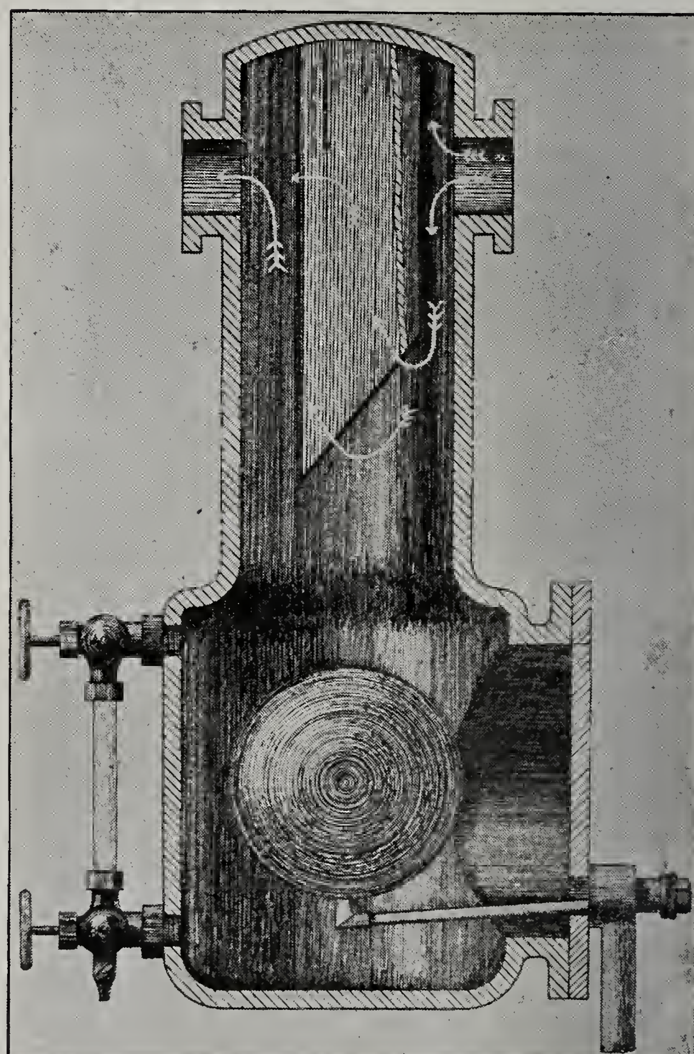


PLATE 5. THE CURTIS SEPARATOR.

by properly shaped passages to the bottom of the separator. At the bottom of the separator is a float attached to a valve, arranged so as to open the drip automatically when the water rises to a certain level.

The Barnard separator is made in two forms. The safety separator, as shown in Plate 6, consists of a vessel with a deflecting plate which guides the current of steam and water to the bottom of the vessel. From thence the steam changes its direction, slowly rises, and passes into the discharge-pipe. In the main body of the separator is a ball, surrounded with a perforated partition, which serves as a guide to its motion. In case of a sudden influx of water beyond the capacity of the drip to remove, the water level rises, carrying the ball, which seats itself at the upper part of the separator, and shuts off the supply of steam to the engine, thus effectually guarding against any accident. For removing the water this separator depends simply on change of direction of the current of the steam.

The Barnard standard separator, however, is constructed on very different plans. This separator consists of an expansion to the pipe, in which are a series of vertical deflecting plates, each provided with a channel for the water striking it, connected with a larger channel leading to the drip-pipe. The steam enters at one end, and must change its direction at each deflecting plate; the particles of water would be projected with considerable velocity on to the plates, and would run into the passage below, where they would be protected from the steam current. From this place the water may be drawn off by the drip at pleasure.

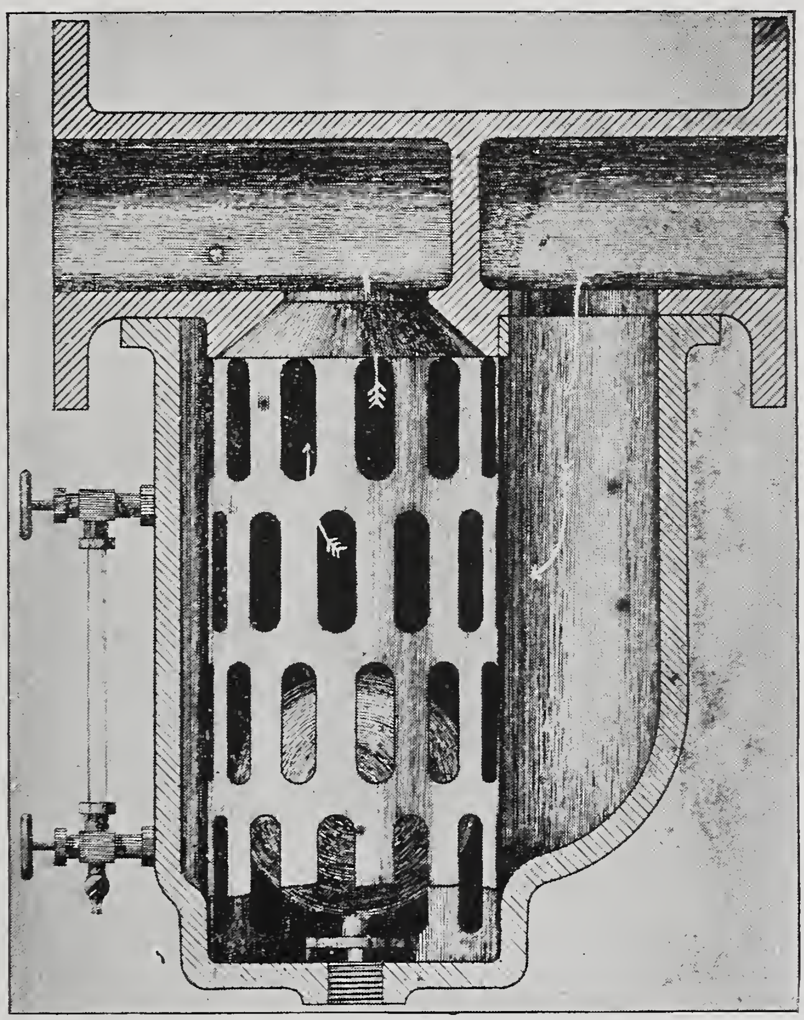


PLATE 6. THE BARNARD SAFETY SEPARATOR.

The Simpson separator, as shown in Plate 7, consists essentially of a cylindrical vessel containing a smaller concentric tube reaching nearly to the bottom. Fixed in the annular space between the two cylinders is a spiral thread. Steam enters either at the top or from the left, as circumstances require, and takes a spiral course between the threads. The water, by centrifugal

force, is thrown against the outer walls, and is free to go to the bottom ; while the steam enters the inner tube through the holes near its lower end, and passes

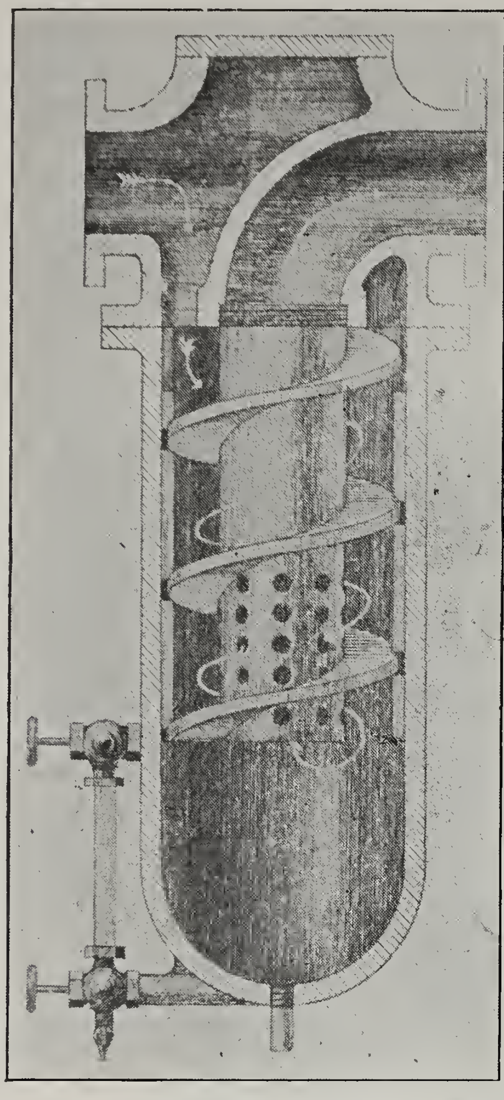


PLATE 7. THE SIMPSON SEPARATOR.

upwards and out. This separator depends for its action almost entirely on centrifugal force, since the velocity of the outgoing steam is fully equal to that of the entering steam.

The pipe separator, as shown in Plate 8, was constructed at Sibley College for experimental purposes. It consists of an outer shell of 6-inch pipe about 6 feet long, into which extended a 3-inch pipe, as shown. The steam entered at the side near the top, and passed down in the annular space surrounding the pipe, thence made an abrupt turn and passed upwards through the outlet-pipe. A series of small holes were drilled in the discharge-pipe, through which the steam could pass. In this separator the steam entering from the small pipe into the large vessel would have its velocity materially reduced, and the entrained water would be thrown out by change of direction, and allowed to settle in the comparatively still current of steam in the separator, from whence it could be removed by opening the drip. The velocity of the outgoing upward current would be in excess of the downward current, a fact that was overlooked in designing the separator.

To determine the highest efficiency possible of mechanical separation of water from the steam, a series of very careful tests were made of all the separators described by G. M. Brill and W. H.

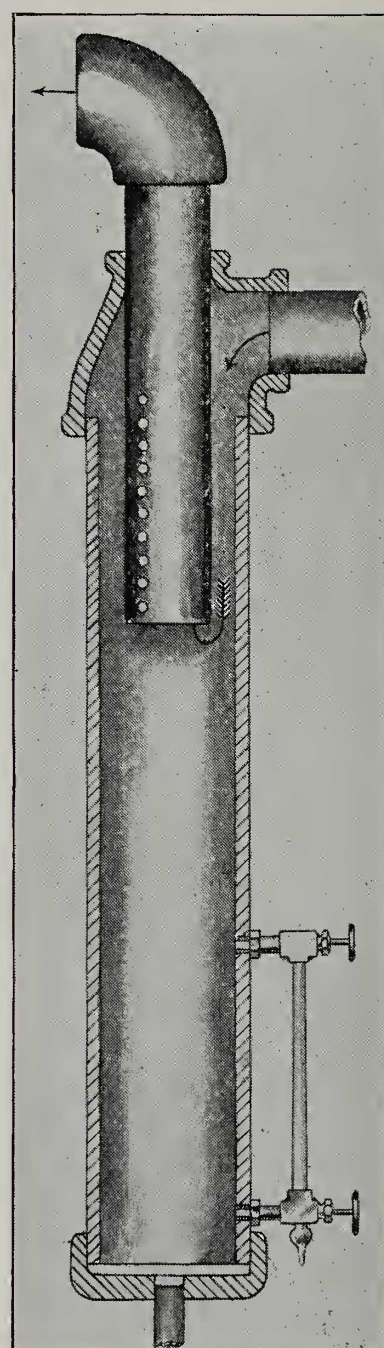


PLATE 8. PIPE SEPARATOR.

Meeker in the Sibley College laboratories, and the writer is indebted to their report for the principal items of interest in this article.

For the test, the separators were arranged as shown in Plate 9. The steam-pipe from the boiler passing through a drum, in which the water could be maintained at any desired level, a calorimeter was arranged to draw a sample of steam before it reached the separator, and another one to determine the quality after it had passed the separator. The steam, after passing through the separator, went to a steam engine, and thence to a surface condenser. Arrangements were made for measuring the pressure before and after leaving the separator. The arrangement finally adopted was only perfected after several trials with the apparatus in different positions, considerable difficulty being experienced in locating the first calorimeter so as to secure a fair sample of steam.

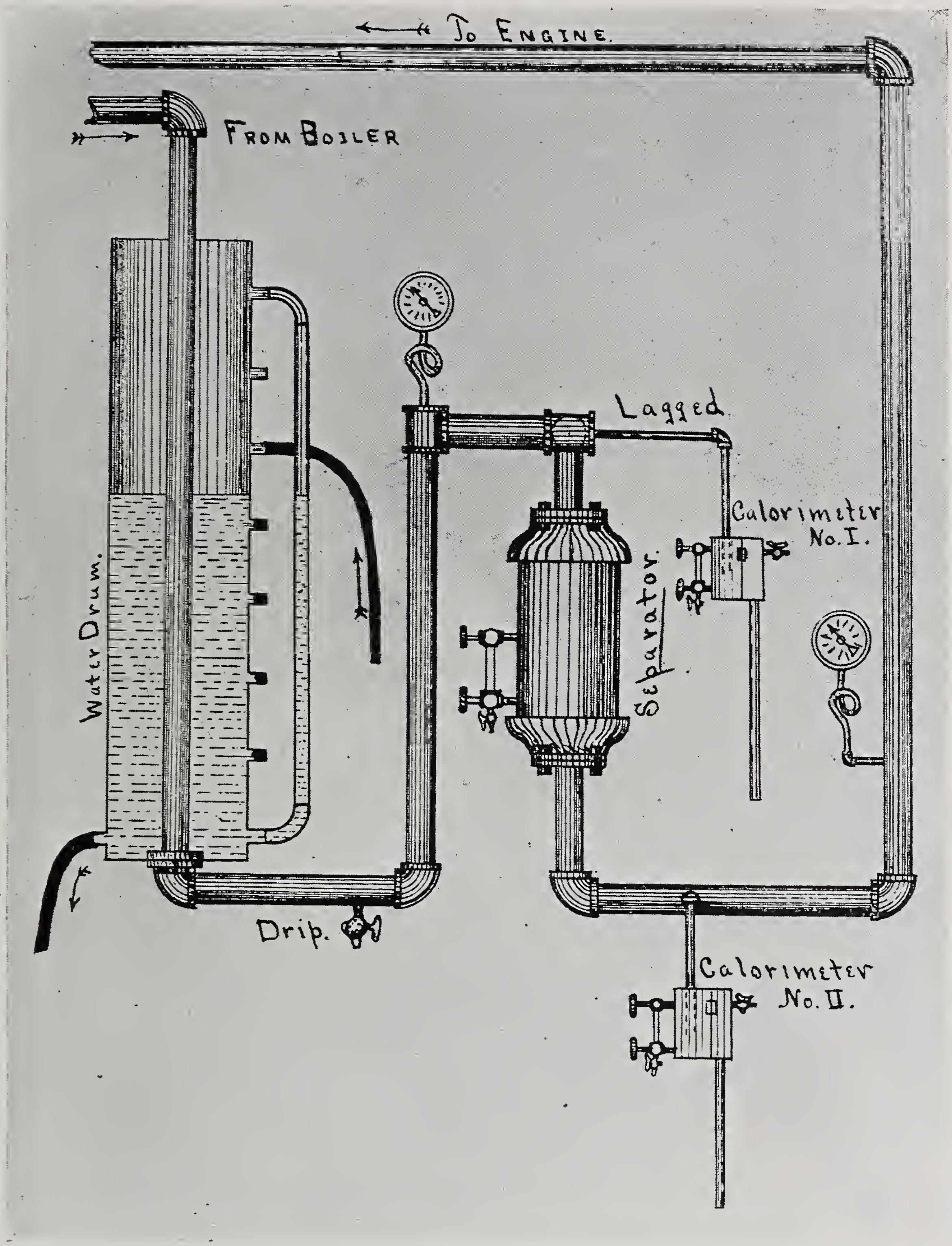


PLATE 9. ARRANGEMENT OF SEPARATORS FOR TEST OF EFFICIENCY.

During the tests, the amount of steam was maintained as nearly constant as possible, that supplied for the 2-inch

separators being at the rate of 800 pounds per hour, that for the 3-inch separators being at the rate of 1200 pounds per hour, or sufficient to run steam engines of 20 and 30 horse-power respectively.

The requirements for a perfectly satisfactory separator may be, perhaps, difficult to state; but it is quite evident that the separator should remove most of the moisture from the steam, without being so much of an impediment as to reduce the pressure to any considerable extent; neither should it cause an excessive loss of heat by the discharge of dry steam at the drip. These tests, the results of which are given, were made not to determine the highest comparative efficiency of the various commercial forms, but to ascertain, if possible, what were the conditions required to successfully remove the entrained water from the steam; and, in presenting the results of the tests here, the endeavor is made to bring out the points of scientific interest only. Very briefly, the results of the tests were as follows, the different separators being designated by letters:

Before Passing the Separator.		After Passing the Separator.			
Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Loss of Pressure, Pounds.	Moisture Removed, Per Cent.
A.*					
76.3	24.0	75.6	14.1	0.7	9.9
84.2	18.2	82.5	14.7	1.7	3.5
83.9	10.9	83.6	9.4	0.3	1.5
82.4	8.1	81.6	5.5	1.8	2.6
79.7	7.1	79.1	5.4	0.6	1.7
76.5	5.7	76.0	4.0	0.5	1.7
81.2	2.6	80.7	1.6	1.5	4.1
B.					
80.4	32.9	79.1	5.2	1.3	27.7
78.1	26.8	77.1	4.7	1.7	22.1
78.9	25.6	78.1	5.2	0.8	20.4
79.3	21.8	79.0	4.4	0.3	17.4
79.6	21.8	77.6	5.3	2.0	16.5
78.1	13.5	77.2	5.5	0.9	8.0
85.8	12.3	85.1	4.9	0.7	7.4
78.7	11.1	78.1	4.3	0.6	5.1
80.6	8.1	80.4	1.4	0.2	7.9
C.					
71.5	52.9	....	2.75	....	50.15
71.5	52.4	69.9	2.80	1.6	49.6
68.75	33.0	67.75	2.6	1.0	30.4
73.5	28.0	72.5	2.6	1.0	25.4
82.25	23.9	81.4	2.6	0.8	21.3
74.3	17.5	73.1	2.75	1.2	14.75
73.0	5.6	72.0	2.6	1.0	3.0
82.25	3.0	81.2	2.1	1.0	0.9
D.					
79.6	31.4	79.3	20.7	0.3	10.7
81.7	28.2	79.4	15.1	2.3	13.1
78.0	26.8	75.2	20.8	2.8	6.0
81.4	25.4	79.2	18.4	2.2	7.0
83.4	17.6	81.0	9.6	2.4	8.0
82.0	11.6	79.6	9.8	2.4	1.8
80.9	6.4	80.2	1.9	0.7	4.5
83.2	5.2	82.3	1.9	0.9	3.3
83.0	2.2	82.3	1.7	0.7	0.5
78.8	1.9	78.0	1.5	0.8	0.4
			9.06	1.55	

* This separator, contrary to expectation, seems to be capable of removing but little moisture from the steam, and can hardly be considered of commercial value. The reason for this will be perceived later.

E.

Before Passing the Separator.		After Passing the Separator.			
Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Loss of Pressure, Pounds.	Moisture Removed, Per Cent.
79.6	27.9	78.9	4.2	0.7	23.7
81.2	25.4	80.7	1.8	0.5	23.6
78.5	24.1	77.4	4.5	0.9	19.6
80.7	18.3	79.9	2.1	0.8	16.2
79.7	17.0	78.9	3.2	0.8	13.8
83.1	16.7	82.5	3.6	0.6	13.1
77.8	11.1	76.9	3.6	0.9	7.5
79.2	10.4	78.2	4.2	1.0	6.2
80.6	6.3	79.7	2.8	0.9	3.5
83.1	3.9	81.7	2.6	1.4	1.3
			3.06	0.85	
F.					
77.4	33.9	76.6	1.2	0.8	32.7
78.3	30.6	77.8	1.0	0.5	29.6
76.2	27.3	74.7	2.2	1.5	25 8
82.0	24.0	81.8	1.2	0.2	22.8
75 6	23.1	75.2	1.4	0.4	21.7
76.6	21.9	76.0	1.2	0.6	20.7
81.4	16.7	80.8	1.6	0.6	15.1
75.2	13.0	74.7	1.2	0.5	11.8
81.4	6.6	80.7	1 0	0.7	5.6
85.8	6.4	85.1	1.0	0.7	5.4
81.5	3.6	81.1	1.0	0.4	2.6
79.3	2.5	78.8	1.0	0.5	1.5
			0.62	1.25	
G.					
80.0	48.1	79.2	1.6	0.8	46.5
75.2	45.7	74.3	2.1	0.9	44.8
76.6	45.6	75.5	1.9	1.1	43.7
73.6	42.0	72.5	2.0	0.9	40.0
78.4	37.0	77.3	2.0	1.1	35.0
80.2	30.5	79.0	1.8	1.2	28.7
81.4	19.6	79.9	1.9	1.6	17.7
80.9	9.9	79.1	2.0	1.8	7.9
78.8	4.7	77.7	1.8	1.1	2.9
86.4	3.9	84.9	1.6	1.5	2.3
81.0	2.2	79.6	0.9	1.4	1.3
78.9	2.0	77.3	1.9	1.6	1.01
			1.54	1.25	
H.					
77.3	29.6	76.4	15.9	0.9	13.7
75.1	24.2	74.2	14.1	0.9	10.1
82.0	20.7	81.5	12.8	0.5	7.9
81.1	19.1	80.1	10.8	1.0	8.3
81.6	18.4	80.7	15.7	0.9	2.7
78.6	17.1	77.7	10.8	0.9	6.2
80.4	11.1	79.4	7.9	1.0	3.2
81.8	5.3	80.8	4 0	1.0	1.3
76.0	2.5	75.0	2.4	1.0	0.1
81.7	2.3	80.4	2.1	1.3	0.2

A careful study of the results of the tests shows not only a wide variation in the efficiency of the various separators, but also indicates a wide variation in the laws which govern the action of the separators. If the efficiency of the various separators is considered as represented by the quality (1 minus the percentage of moisture) of the escaping steam, we observe, that for some of the separators the efficiency remains constant and independent of the water in the entering steam, while in others the efficiency decreases directly with the moisture present in the original steam; in others still the efficiency is constant until the amount of moisture exceeds a certain per cent., and then it rapidly diminishes with increase of water. It is seen that a certain amount of moisture, possibly less than 1 per cent., is not removed by the best separators; but any amount greater than this is removed, leaving the exhaust of uniform quality. A study of the forms which give the different results shows that while in all cases water is readily precipitated by change of direction, unless it passes at once into passages where it cannot be acted on by the dry steam, it will be again taken up and discharged from the separator with the steam. This conclusion seems the more reasonable since in each case the essential

G.—[6-inch or 3-inch Pipe.]

Before Passing the Separator.		After Passing the Separator.			
Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Steam Pressure by Gage.	Moisture in Steam, Per Cent.	Loss of Pressure, Pounds.	Moisture Removed, Per Cent.
Run I.*					
	37.6	80.0	0.95	Very Small.	38.65
	32.3		1.0		31.30
	25.3		0.96		24.34
	10.8		0.96		9.84
	6.6		0.95		5.65
	5.8		0.95		4.85
Run II.†					
	45.5	80.0	0.75	Very Small.	44.75
	31.1		0.65		30.45
	25.0		0.75		24.25
	20.1		0.8		19.3
	11.0		0.7		10.3
	5.1		0.8		4.3
Run III.‡					
	41.2	80.0	0.8	Very Small.	40.4
	29.5		0.65		28.80
	25.9		0.75		24.15
	19.5		0.85		18.60
	10.5		0.8		9.7
	6.3		0.85		5.45
Run IV.§					
	36.0	80.0	0.65	Very Small.	35.35
	25.3		0.8		24.5
	23.4		0 65		22.75
	19.5		0.7		18.8
	12.7		0.75		11.95
	5.7		0.9		4.8

* Inlet full size, 6 inches diameter; discharge chamber full size.
† Inlet reduced to 5 inches.
‡ In.et reduced to 4 inches.
§ Inlet 6 inches; area for upward flow reduced to the same amount by blocking.

difference between those separators which gave the highest efficiency and the others seemed to be better provision for keeping the water thrown down from contact with the current of steam.

The tests also indicated that the amount of water that would be precipitated by merely increasing the volume was comparatively insignificant for the cases investigated, but that the water can readily be separated from steam by action of the inertia due to its greater weight, and that for the successful removal of entrained water from the steam are needed:

1. Abrupt change of direction. 2. Special conduits to receive and carry off the water precipitated, and keep it from contact with the dry steam. 3. Sufficient volume to afford temporary relief in case the priming is excessive and more than can be removed by the drip. 4. Automatic action of the drip, which may be secured by use of the steam-trap or of the "steam-loop."

The tests made indicate the possibility of accomplishing the removal of nearly all the moisture contained in the steam, without reducing the steam pressure more than 1 or 2 pounds, and of providing the steam plant dry steam, regardless of the quality of that supplied by the boilers.

The tests shown in the table on preceding page were made to determine the effect of changing the relative volumes of inlet and discharge chambers. The results of this test show that volume alone has little effect on the efficiency of separation of water from steam.

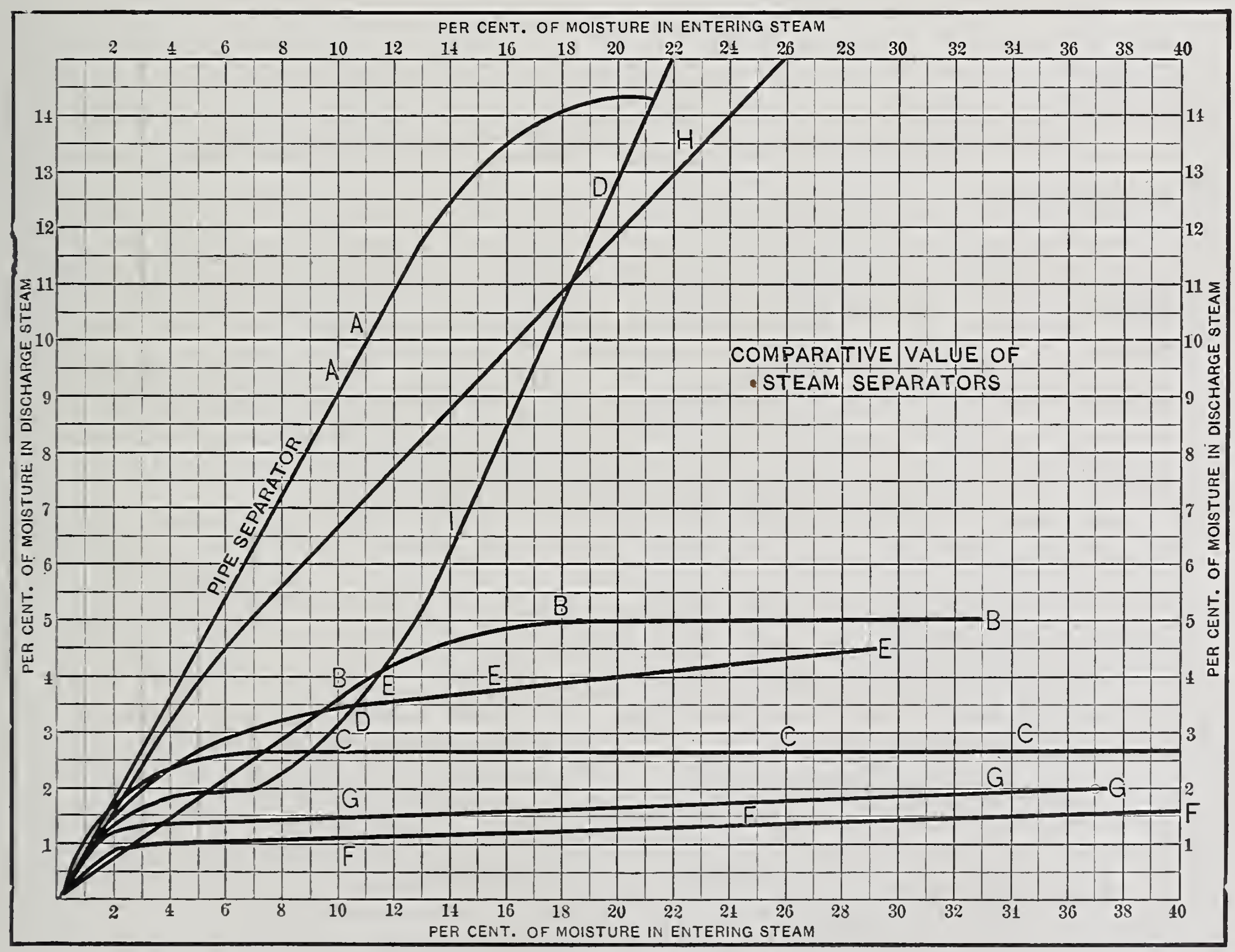


DIAGRAM SHOWING RELATIVE VALUE OF SEPARATORS TESTED.

DISTRIBUTION MAINS AND FIRE SERVICE.—II.

By J. T. Fanning, Mem. Am. Water Works Asso.

TO find the capacities of the several distribution pipes to supply fire streams alone, divide column six of rate of flow in Table No. 5 (in preceding issue) of maximum allowable frictions by .4, the assumed rate of flow in million gallons for one stream, and we have—

DIAMETER OF PIPE.	6	8	10	12	14	16	18	20	24	27	30 in.
NUMBER OF STREAMS.	1	2	4	7	10	13	18	23	35	44	55

The domestic and other drafts must of course be allowed for in the final determination of diameter of pipe. These numbers of streams are stated for pipes which receive their water from one end only; but if the flow comes freely from both ends of the pipe toward hydrants on the same section, then the capacity of the pipe is doubled, and the number of hydrants on the same section may be doubled.

If we compare a given flow from one end of a pipe to an outlet at its center with the same total flow from both ends to the outlet, we find the loss of head in the second case to be but one-fourth the loss in the first case.

This matter of double flow toward fire hydrants is of significant importance in the fire-service system, and it is a strong argument against many of the dead ends that might be made contributors of flow to hydrants.

Friction Heads for Given Numbers of Streams.—The friction losses in the pipes for the given number of streams are to be summed, beginning with the hydrant branches, then in the distribution pipes which supply them, then in the sub-mains, and then in the principal main, back to the pumping machinery or reservoir.

Such frictions are tabulated for pipes of different diameters in Table No. 6, and are for a flow in one direction. The volumes may apply to combined streams or to equal combined streams and domestic drafts.

Diagram of Friction Heads.—A diagram is presented herewith illustrating the above table, from which the friction head in each 1000 feet of pipe for given discharges may be taken.

The diagram will show by inspection the friction of the combined fire and domestic flows in the several diameters of pipes within the range of ordinary velocities of flow in public water-supply systems.

Hydrant Sections.—The computations already given of losses of pressure and head when relatively large volumes of water are forced through small, straight pipes and hose have shown and emphasized the error of attempting to use mains that are too small for their legitimate work. Such a mistake is more glaring when the crooked passage through a hydrant branch and post hydrant is considered.

The post hydrant and branches, as often used, consume eight to ten pounds pressure when a single good fire stream is flowing through them, or practically as much as a fifty-foot length of hose.

The hydrant branch is often too small and the angles through which the stream must pass, both in leaving the main and in the hydrant, are too sharp. If the main pipe ought to be eight inches diameter to flow the water in one direction for two strong streams, then the hydrant branch and barrel ought certainly to be eight inches diameter for the same duty. They are too often mistakenly made four inches diameter for one stream, or six inches for two streams. It is apparent that, when strong streams are desirable, the object may be in part defeated by small hydrant branch and hydrant sections, even though the pressure is good in the mains.

The additional cost of the second nozzle on a post hydrant is small, so that when the pressure in the main ad-

mits of direct connection of leading hose to the hydrants, as in high-reservoir or direct-pressure systems, the advantage of the second stream may far overbalance the additional cost of the nozzle.

An independent gate in the hydrant head for each nozzle is sometimes of exceeding value, and worth much more than its cost.

The value of a flush hydrant located line. This is as essential for a good fire service as mains of adequate diameter.

Hydrants should also be near together so that the line of hose may be short. The hose may have to be lengthened down alleys or through or over one or more buildings to reach the burning building.

In the dense portions of cities there should be a hydrant which is proportioned for at least two strong streams

TABLE NO. 6.

HEAD LOST BY FRICTIONS IN SMOOTH PIPES IN EACH 1000-FOOT LENGTH.

FRICTION HEADS IN FEET FOR GIVEN DIAMETERS AND NUMBERS OF STREAMS.

Number of Streams of .4 Mil. Gals. each.	Total Discharge in Mil. Gals.	6-Inch Pipe, Feet.	8-Inch Pipe, Feet.	10-Inch Pipe, Feet.	12-Inch Pipe, Feet.	14-Inch Pipe, Feet.	16-Inch Pipe, Feet.	18-Inch Pipe, Feet.	20-Inch Pipe, Feet.
1	0.4	7.8	1.65	0.62	0.24	0.12	0.05	....	....
2	0.8	27.0	6.90	2.30	0.92	0.43	0.22	....	....
3	1.2	....	15.10	5.00	2.00	0.93	0.48	0.27	0.13
4	1.6	....	....	8.70	3.50	1.64	0.84	0.53	0.25
5	2.0	....	....	12.17	5.32	2.47	1.24	0.78	0.40
6	2.4	....	....	....	7.60	3.49	1.77	1.06	0.58
7	2.8	....	....	....	10.20	4.70	2.38	1.37	0.77
8	3.2	....	....	....	13.05	6.06	3.07	1.74	0.97
9	3.6	....	....	....	....	7.60	3.87	2.14	1.24
10	4.0	....	....	....	....	9.30	4.77	2.63	1.54
11	4.4	....	....	....	....	11.20	5.72	3.64	1.83
12	4.8	....	....	....	....	13.15	6.74	3.70	2.16
13	5.2	....	....	....	....	....	7.84	4.33	2.54
14	5.6	....	....	....	....	....	9.08	5.04	2.93
15	6.0	....	....	....	....	....	10.40	5.74	3.36
16	6.4	....	....	....	....	....	11.30	6.53	3.80
17	6.8	....	....	....	....	....	12.45	7.40	4.24
18	7.2	....	....	....	....	....	....	8.25	4.73
19	7.6	....	....	....	....	....	....	9.13	5.28
20	8.0	....	....	....	....	....	....	10.00	5.83
21	8.4	....	....	....	....	....	....	10.90	6.40
22	8.8	....	....	....	....	....	....	11.70	7.00
23	9.2	....	....	....	....	....	....	....	7.67
24	9.6	....	....	....	....	....	....	....	8.33
25	10.0	....	....	....	....	....	....	....	9.00

over the branch at the intersection of the street mains has been often urged for use in the dense portions of large cities, because its capacity there for several streams is greatest and its friction losses least, and such hydrants have had a considerable use in the eastern New England cities.

Nearly as favorable results may be obtained if a large branch pipe, equivalent to the main, is taken to a hydrant with large valve and barrel at the curb at each street intersection, and in the commercial and manufacturing sections a like hydrant at a central point between the street corners on the principal streets. This arrangement is not less desirable for a steam fire-engine service than for a direct-connection hose service.

The intermediate hydrants are likewise valuable on high grounds where pressures are light for direct connections.

Assistance of Neighboring Fire Departments. — Nearly every large city

whose pipe system has been inefficient can cite its own experience when its entire fire department could not cope with a fire that had a good start, and the fire departments of neighboring cities came to the rescue with steamers and hose carriages. Chief Damrell testified before the commission that investigated the Boston Great Fire, in 1872, that he telegraphed for assistance to every town and city within fifty miles of Boston. There was a hearty response with between forty and fifty steam fire engines; but it then proved that the water mains and fire hydrants were inadequate, and also the diversity in threads on hydrant nozzles and hose couplings was a source of delay and disappointment.

hydrants in use. At a Providence fire, in 1877, there were at the same time in use seventeen streams direct from hydrants and eight streams from steamers, estimated to have been using about 4500 gallons of water per minute, or a delivery equivalent to sixteen of our standard streams. At the Bedford-street fire in Boston, in 1889, there were reported twenty-five hydrants in use, supplying fifty-two steamers delivering eighty hose streams. The maximum consumption of water by hose streams was estimated at 20,000 gallons per minute, or at the rate of 28,800,000 gallons per twenty-four hours.

The estimated total quantity used on the fire during the first twenty-four hours was 14,000,000 gallons. At the recent Seigel-Cooper fire in Chicago there were reported twenty-five steam fire engines in use.

TABLE NO. 7.

RELATIVE COSTS AND CAPACITIES OF PIPES.

Diameter of Pipe, Inches.	Cost, Laid.	Capacity, Million Gallons.	Capacity, No. of Hose Streams.
6	$0.79	.0593	1
8	1.07	0.978	2
10	1.40	1.748	4
12	1.75	2.792	7
14	2.16	4.003	10
16	2.64	5.339	13
18	3.10	7.138	18
20	3.63	9.168	23
24	4.95	13.912	35
27	5.79	17.731	44
30	6.82	22.207	55

Precautions. — In citing, before, ten strong streams in the suburbs and eighteen or twenty strong streams concentrated in the business centers of cities as requirements for the ordinary fire service of single fires, these were not intended to present maximum requirements or to cover two or three large fires at the same time. During a recent fire at a grain elevator in Minneapolis the intensely hot air carried masses of large burning cinders high in the air, and they were scattered not only among frame cottages and out-buildings of wood within half a mile to windward, but also over wood yards and lumber yards until all the fire hydrants in a large area were in use.

At the American Print Works fire in Fall River, in 1874, there were forty

Superintendent Darling, of Pawtucket, has told us that at the burning of the lumber yard in his city he had fifty-two hose streams in use at the same time, and that the use of so many streams prevented a conflagration that was liable to have destroyed a million dollars' worth of property.

Relative Costs and Capacities of Mains.—The capacities of water mains increase relatively faster than their costs. For instance, let us assume the cost of cast-iron pipes adapted to 100 pounds per square inch pressure to be $30 per net ton, delivered at the trench. Then in a suburb where the streets are

not paved the costs of the pipe laid complete and delivery capacities of the pipes, on the velocity of flow and frictional bases above stated, will be substantially as follows, if we state capacities in million gallons per twenty-four hours as the unit.

In changing a pipe from an eight-inch to a ten-inch diameter we increase the cost thirty per cent. and the capacity seventy-nine per cent. If we change a pipe from ten-inch to twelve-inch diameter the cost increases twenty-five per cent. and the capacity sixty per cent. And so in the larger diameters, if we change the pipe from a twenty-inch to a twenty-four inch we increase the cost thirty-six per cent. and the capacity fifty-two per cent.

Duplicate Flow.—In considering an orifice or jet at the center of a long pipe, say in a suburban street, we found that if the flow could come with equal advantage from two directions a jet might be duplicated without greater loss of pressure than when the single flow came from one direction only, and also that by giving flow from two directions to one jet, and thus reducing the velocity one-half, the loss of pressure was only one-fourth that due to the single flow.

Here is a suggestion to be kept constantly in view in planning a new system and in the extension of an old system of pipes. It not only gives double capacity to the combined fire and domestic service, or saves three-fourths of friction head, but it gives two channels of supply to every point, so that if in case of extensions or repairs one line is shut off another line is still open, and the domestic and fire service maintained. Neither fire or domestic service should be subject to the contingency of one line of supply main only.

The original plan of pipes and plans of extensions in growing cities also must anticipate the increase of capacity of mains inevitably necessary, and foresee where a larger reinforcing pipe will best be placed when it is needed, and its relations to the entire system.

The duplicate flow advantage applies as well to the hose as to the distribution pipe. If the jet is far from the hydrant and the friction loss excessive, the loss of head is at once reduced three-fourths by duplicating the hose from hydrant to play-pipe ; or loss of pressure may be greatly reduced by using hose of greater diameter so far as it can lay on the ground.

The increasing domestic draft of water in growing cities often leads to such increased frictions in the mains that their value for fire service is much reduced also. For instance, the fountain in New York's city hall park used to throw its large jet sixty feet high, and the water would flow into the highest story of the down-town buildings with ample force, while now the head from the reservoir is almost entirely consumed by friction in the distribution pipes.

The proper remedy in such cases is to make the mains adequate for their legitimate duty. In many cases a tank standpipe on the side of the distribution, opposite to the reservoir or pumps, is a valuable aid both in supplying water and reducing friction from the main supply.

Such an elevated tank holding one-half million gallons of water will alone supply ten 1⅛-inch eighty-foot streams from three to four hours.

Control of Spreading Conflagrations.—The objection may be anticipated that the ten suburban streams or twenty urban streams before mentioned as serving for ordinary fires are entirely inadequate for great emergencies, and that such fires as those originating in the grain elevator and lumber yard above mentioned will be cited.

The first answer must be that the ordinary fire service is not, and usually for financial reasons cannot be, proportioned to conquer great conflagrations. Its prime object is to control and then stop a fire in its early stage, and it must be the most adequate and effective service for this duty which the present circumstances will permit, and reinforced with all electrical and mechanical aids that science offers, so that knowledge of the fire shall be given early and attack on the fire may be prompt, energetic, and successful.

Let us consider further what may be done with say ten good streams. The standard selected for this discussion is 1⅛-inch diameter stream, with force to reach a vertical height of eighty feet, and

the mains proportioned so that the required number of streams may be given with the flow in one direction, equivalent single flow, in the distribution pipes. If the fire is already hot, then a few heavy streams will be most effective, and there may be used eight 1¼-inch or seven 1⅜-inch streams, which will take nearly equal total volumes of water and have equal forces of jets.

If a scattering suburban fire requires more than ten 1⅛-inch streams, we may put their equivalent total discharges of water into one-inch diameter streams as follows:

14 streams of 70 feet height.
16 " " 60 " "
18 " " 50 " "
20 " " 40 " "
24 " " 30 " "

Or if the same total discharge of water is used in ⅞-inch streams there may be

15 streams of 80 feet height.
18 " " 70 " "
20 " " 60 " "
22 " " 50 " "
26 " " 40 " "

Then if the distribution system of mains is planned for double flow through two or more mains, as is desirable to prevent a hydrant being out of use by a shut-off of one of its approaches, the numbers of hydrant streams named above may be doubled, or the fire may be fought with 1¼-inch or 1½-inch streams by doubling or the use of enlarged hose, or the upper story of a warehouse may be flooded by a portable water-tower with a 1⅝-inch stream, and still there will be water and pressure for a number of ⅞-inch streams available to put out the incipient blazes to the windward among low buildings.

A hot fire must be attacked with streams of large volumes of water that strike with force, for puny streams are but converted into vapor before they pass through the heart of the flame.

Large and strong streams are best had from near hydrants and through short hose. An increased number of hydrants is often cheaper than increased power at the pumping station or an increased elevation of a reservoir, and is always cheaper and more effective than long fire hose.

TABLE No. 8.

COMBINED RATE OF FIRE SERVICE AND DOMESTIC FLOW.
(DIRECT-PRESSURE SYSTEM.)

Population.	Rates of Flow for Fire Service, Mil. Gals.	Number of Fire Streams.	Mean Rate of Flow for Domestic Service, Mil. Gals.	Combined Rate of Fire and Domestic Flow, Mil. Gals.	Diameter of a Single Main, Inches.
4,000	3.9	7	.20	4.10	14
5,000	4.10	8	.25	4.35	16
6,000	4 30	8	.30	4.60	16
8,000	4.65	9	.45	5.10	16
10,000	4.90	9	.60	5.50	18
15,000	5.50	10	1.00	6.50	18
20,000	5.90	11	1.40	7.30	20
25,000	6.25	12	1.90	8.15	20
30,000	6.50	12	2.40	8.90	24
40,000	7.10	13	3.40	10.50	24
50,000	7.50	14	4.40	11.90	24
60,000	8.00	15	5.40	13.40	27
75,000	8.75	16	7.10	15.85	27
100,000	10.00	18	10.00	20.00	30
125,000	11.25	21	13.10	24.35	33
150,000	12.40	23	16.00	28.40	36
175,000	13.50	25	19.00	32.50	36
200,000	14.50	27	22.00	36.50	30 & 27
250,000	16.60	30	28.00	44.60	33 & 30
300,000	18.30	34	34.00	52.30	33 & 33

Combined Domestic and Fire Flows.—The conditions of fire risks in different cities, even of equal populations, are so unlike that rigid rules are not generally applicable as to the proper volume of flow in the mains for fire services. The variableness may be magnified when the combined fire and domestic rates of flow are considered. In a majority of the cities the influences governing flow for both services are nearly similar, and in those we may assume for a general computation that the principal mains leading out from the reservoir or from direct-pressure pumps will be proportioned for rates of flow to given populations substantially as in the Table No. 8, when hose streams are taken direct from the hydrants.

A study of the local conditions of a given city will show when its pipe flow will not approximate closely to the table, and will readily suggest the degree of variation therefrom.

It is to be remembered that in many cities the domestic draft of water is quite variable; therefore when the principal mains are proportioned for mean daily rates of flow, as computed in Table No. 8, there will be some lack of strength in the respective given number of hose streams at such times of the day or season as the domestic draft is in excess of the mean daily rate for the year.

In the last table the consumption per capita is assumed to gradually increase from 66⅔ gallons daily when the population is 15,000 to 100 gallons daily when the population is 250,000.

When steam fire engines are used to take the water from the hydrants a temporary drop in the domestic pressure may be admissible during the brief period in which a fire is being conquered. Frequently, in connection with the steam fire-engine hose service the domestic consumption may be treated in the computation as though uniformly 66⅔ gallons daily per capita for all populations.

The combined domestic and fire rates of flow and relative dimensions of mains will then compute as in the above table.

In this last table of subdivided mains the allowance of frictional head per thousand lineal feet of pipe is taken slightly less than in Table No. 5.

The frictions in large pipes are much less for given velocities of flow than in small pipes, also the coefficients of flow vary materially with change of velocity and with change of diameter.

These influences are not to be overlooked in computing subdivided mains,

TABLE No. 9.

COMBINED RATE OF FIRE SERVICE AND DOMESTIC FLOW.
(STEAM FIRE-ENGINE SERVICE.)

Population.	Combined Rate of Fire and Domestic Flow, Mil. Gals.	Diameter of a Single Main, Inches.	Usual Maximum Friction Head per 1000 Feet of Pipe, Feet.	A Proper Maximum Rate of Flow in the Single Main, Mil. Gals.	Subdivided Mains, Equivalent to the Single Main.
15,000	6.500	18	6.78	6.56	Two 14-in. diam. Mains.
20,000	7.233	20	6.34	8 41	Two 14-in. diam. Mains.
25,000	7.917	20	6 34	8.41	One 16-in. and one 14-in.
30,000	8.500	20	6.34	8.41	One 16-in. and one 14-in.
40,000	9.767	24	5.60	12.80	Two 16-in.
50,000	10.833	24	5.60	12.80	One 18-in and one 16-in.
60,000	12.000	24	5.60	12.80	Two 18-in.
75,000	13.750	27	5.13	16.64	Two 18-in.
100,000	16.667	27	5.13	16.64	Two 20-in.
125,000	19.583	30	4.78	21.20	One 24-in. and one 18-in.
150,000	22.400	30	4.78	21.20	Two 24-in.
175,000	25.167	33	4.48	26.40	Two 24-in.
200,000	27.833	33	4.48	26.40	One 27-in. and one 24-in.
250,000	33.267	36	4.26	32.60	Two 27-in.
300,000	28.300	40	4.00	42.20	One 30 in. and one 27-in.

as the subdivisions do not follow quite proportionately with the ratio of square root of the fifth power of the diameter of the pipe.

If there is in connection with the pipe system a considerable use of hydraulic power by motors, goods hoists, and passenger elevators, or a considerable draft for ornamental or for irrigation purposes, the extra flow must be allowed for in computing the frictions in those portions of the water mains having the extra flow.

Fire Service versus Fires.—Often the cost relatively of properly proportioned mains is an obstacle difficult to overcome. Often the necessity of properly proportioned mains is not sufficiently appreciated by municipal boards to receive a sufficient appropriation. Often little heed is given to an assertion, even though well supported by facts, that such increased appropriation as is necessary to insure a well-proportioned pipe system will for each thousand dollars of additional expenditure probably save from destruction at least $100,000 in value of property.

While no city fire-service mains can be expected to control a great conflagration until it has almost burned itself out, no municipality can afford to have its service mains unequal to powerful and successful attacks on one or more fires, according to their magnitude in their early stages.

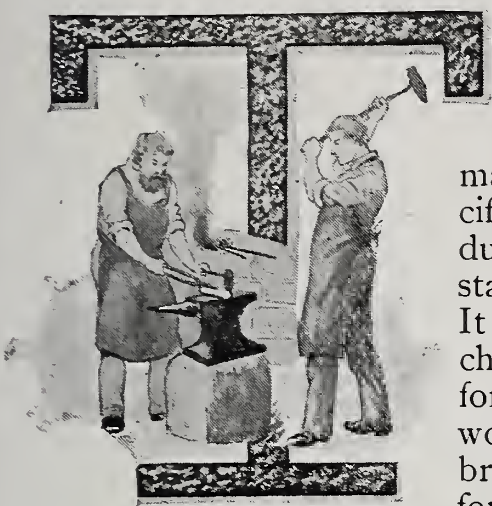
It is the earnest hope of the writer that these few hints and suggestions will emphasize the value and necessity of carefully planned and constructed distribution-pipe systems for the combined fire and domestic water service of cities, and will also emphasize the value of well-designed fire hydrants and stop valves that are not undue consumers of head pressures.

Careful and adequate provisions in construction of the essential details will lead to efficient fire systems that will fulfill the stated objects for which the fire service is planned.

If this object is fulfilled in any system where there is also an efficient fire department, there is little probability of a great conflagration gaining sway within the command of that system and department. A match of strength comes betimes in every city between fire and fire service, and the fire department is hampered if the mains do not respond. Each city has inevitably to choose which is the cheaper, which is the better: a conflagration almost surely impending with dire disaster, or an efficient fire service which makes the conflagration almost impossible.

ÆSTHETICS IN MACHINE DESIGN.

By Professor John H. Barr, M.E.



THE watchword of the machine designer is utility. He creates a machine for a specific duty, and this duty must be constantly in his mind. It may be that a machine is demanded for shaping metal or wood, for weaving fabric, or sewing cloth, for cutting grain, for printing, or for transforming and transferring energy. In each and all of these cases the designer must not overlook the work to be done; the nature of the energy available for doing this work; the facilities at hand for building the machine; the limitations imposed by obtainable and permissible materials; the cost, not only of construction, but of maintenance, which involves durability, convenience in operation, in adjusting, and in making repairs; the permanence of adjustments, and allowable departure from absolute accuracy in the finished product must also be considered.

There are a few parts of a machine to which mathematical analysis can be applied with some satisfaction; there are a great many other features which can only be determined upon by the judgment, skill, and talent of the designer. It is well known that many of the most successful designers use few figures; one of them has said that he would rather accept the judgment than the calculations of any good designer of his acquaintance. Even in the technical schools, where, it is commonly believed, every possible thing (and many impossible things) is subjected to mathematical analysis and computation, there are many details which cannot possibly be settled by such means. Designing is more art than science. It is the art of producing a construction capable of meeting the above-mentioned requirements, often complicated by other special conditions. This must be done in such a way as to reconcile, to the highest possible degree, the conflicting elements entering into the problem.

These strictly utilitarian elements are undoubtedly of the first importance in successful practice; but another question, the æsthetic, is secondary only to these; and, in many cases at least, it should probably be included among the prime requisites.

The neglect of appearance in the design of any permanent machine is inexcusable because unnecessary, and unnecessary because inexpensive.

This is not to be considered as a plea for floral decorations, for Corinthian columns, for moldings and cornices, or for red paint and yellow stripes; nor even for an excess of less objectionable ornamentation, such as polished brass and drawfiled surfaces. These latter may be very effective in the proper place, but no array of them will compensate for the absence of easy, natural lines and harmonious proportions.

The architectural designer is expected to devote much attention to the artistic side of his work, and is not only permitted to but encouraged in spending time and money for æsthetic effect. This license is at times abused, when we see structures that appear to be not much more than mere racks upon which to group ornaments, important considerations of utility and convenience being made secondary. Such buildings are perhaps no better or no worse than machine constructions in which no thought has been given to matters of taste and appropriateness.

They are *better*, inasmuch as an attempt is made (misguided though it may be) to gratify the desire for the beautiful; they are *worse*, because money has been wasted in a way to offend the

taste of a cultivated and discerning observer.

Few exact principles can be laid down for attaining the much-to-be-desired end of greatest artistic effect without sacrifice of the essentials of the machine. As utility is *the* consideration in constructing a machine, simplicity and harmony should be the aims of the designer in striving for the best and most appropriate appearance. Ornamentation for the sake of ornament is to be rigidly avoided. It is a very bad design, like disagreeable medicine, that needs a sugar coating.

All metal should be placed, so far as is consistent with the imposed conditions, in the lines of the forces transmitted by it. It is often, of course, absolutely impossible to secure this disposition of metal, and in such cases the departure from these natural lines should be as small as possible and by smooth lines. All intersecting flat surfaces should be joined by easy curves, and outside corners (except when machined and used as bearing surfaces) should be well rounded.

The box section is usually preferable to the ribbed and flanged sections in cast-iron members, such as frames for engines and machine tools, and where the stresses called out in operation are made up of torsion combined with flexure, tension, or compression. The box section is equally well adapted to resist these latter actions, and is superior for torsional resistance. This section also affords a more convenient surface for the attachment of other parts than is found in the ribbed section, and any desired thickness of metal is secured by changing the dimensions of the cores without affecting the external appearance.

In many cases, such as vertical-engine supports and the legs of lathes, or other tools, the appearance of the box ection is approached by a flanged (channel) section, avoiding the use of cores. Whenever flanges are used they should be on the inner surface, unless special reasons for the contrary exist. Smooth external surfaces are much neater and more easily kept clean. Speaking of lathe legs, it may be observed that in no simple machine member is there to be seen much more variety of form. We find legs with convex curves, legs with concave curves, legs with compound curves, straight legs and taper legs, and all possible modifications of these. The form in which the legs taper gradually from the bed to the lower cross-brace, and then spread to a widened base with an easy curve, is perhaps as good as can be given. The metal is very properly placed, the machine has the stability due to a large base, and the legs do not offer as great an obstruction as if carried directly from the bed to a base of equal width. The compound curve, so frequently seen, obstructs the space about the lathe more, and the metal is not so well disposed, while it offers no compensating advantages. A bow-legged lathe is no more graceful than a bow-legged man, and not nearly so excusable.

An engine bed is an example of a complicated part subjected to various and variable straining actions. No part offers the designer greater opportunity to display his skill.

In the center-crank type there is less difficulty in distributing the metal properly, and Professor Sweet has shown us, in his "straight-line" engine, what an able designer can attain. With the overhanging-crank engines it is not possible to get the ideal distribution of material. The girder frames of the Corliss engines and the "Tangye" bed are good examples of what has been done.

It is impossible in this brief sketch to go into many details; but all other parts than the frames and supports of machines add to, or detract from, the effect as a whole. The wonderful progress that has been made is well shown by the recent trade catalogues of machinery. The designs of the more progressive builders are all characterized by outlines of extreme simplicity, with no unnecessary moldings, ledges, cornices, etc.; and even the most conservative manufacturers, while some of them have not found it in their hearts to lay aside or burn up their old idols, have accepted the newer ideas for their more recent designs.

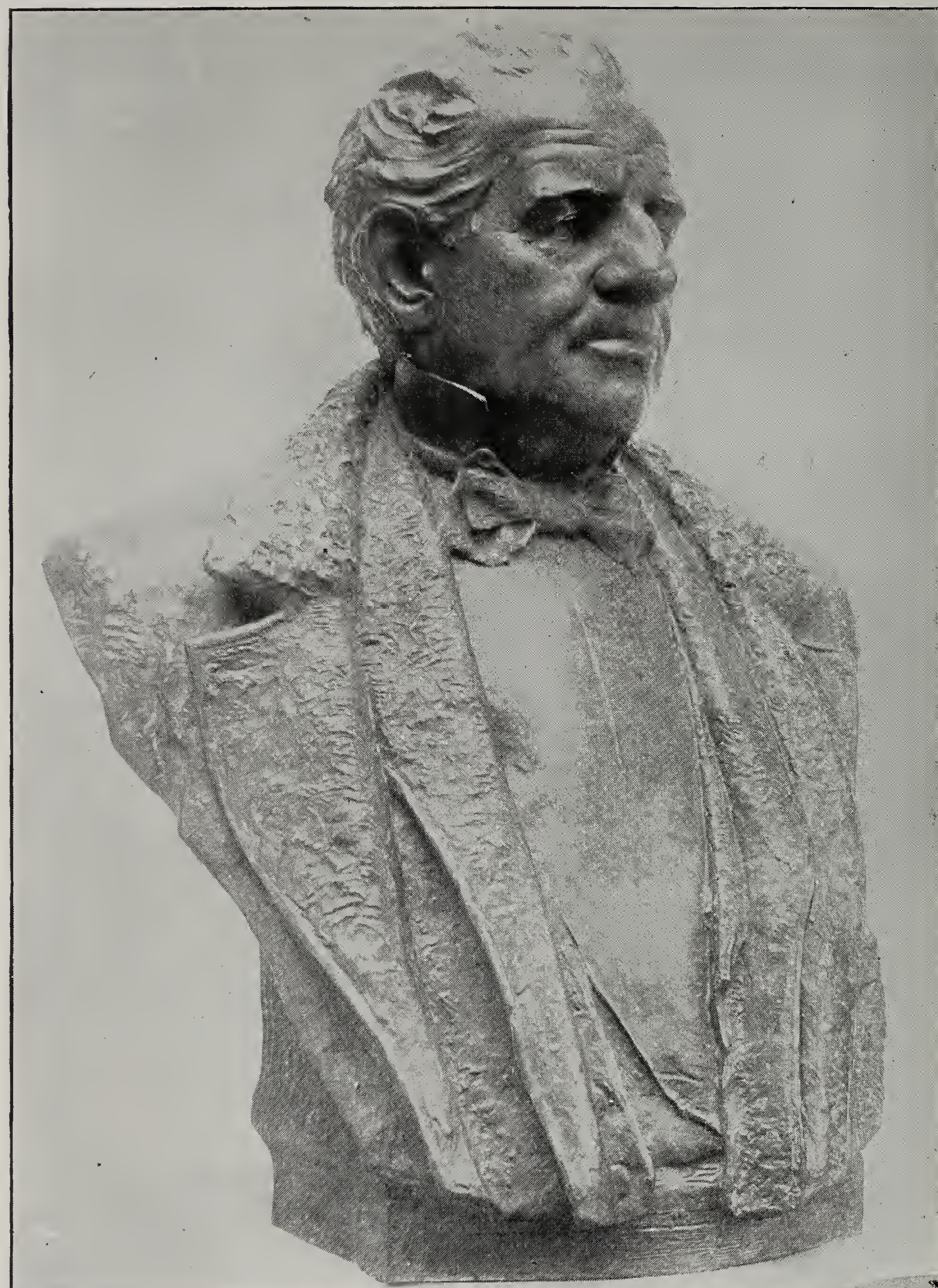
Probably in no place in this country is the "growth in grace" more strik-

ingly shown than in two of the Chicago water-works stations.

The interior of the North-Side Station is filled with specimens of Greek architecture, reminding one more of a classical museum than of an engine room; yet these same engines were looked upon, not many years since, as engineering achievements of very considerable note.

At the Harrison-Street Station, on the west side, are to be seen two great triple-expansion engines by that king of designers, Mr. Edwin Reynolds. Every line of them is pleasing; every feature is an essential part; the whole is a magnificent exemplification of the majesty of machinery. Yet adaptability and utility have not been sacrificed; the working parts are accessible, every convenience for manipulation is provided, and with all this the performance of this plant is one of the most economical of which we have record. As a result of the official trial it stands credited with a "duty" of about 140,500,000 foot pounds per 1000 pounds of steam. This shows that appearance need not be attained at the sacrifice of other desirable qualities.

Is the æsthetic side of machine design worth consideration? *Does i pay?* A glance at the work done by the builders who do the business and make the money to-day answers mos emphatically, Yes.



A. A. MACNEIL, SCULPTOR. CASTING BY GORHAM & CO, NEW YORK.

BUST OF HIRAM SIBLEY, FOUNDER OF SIBLEY COLLEGE, ERECTED BY THE TRUSTEES OF CORNELL UNIVERSITY.

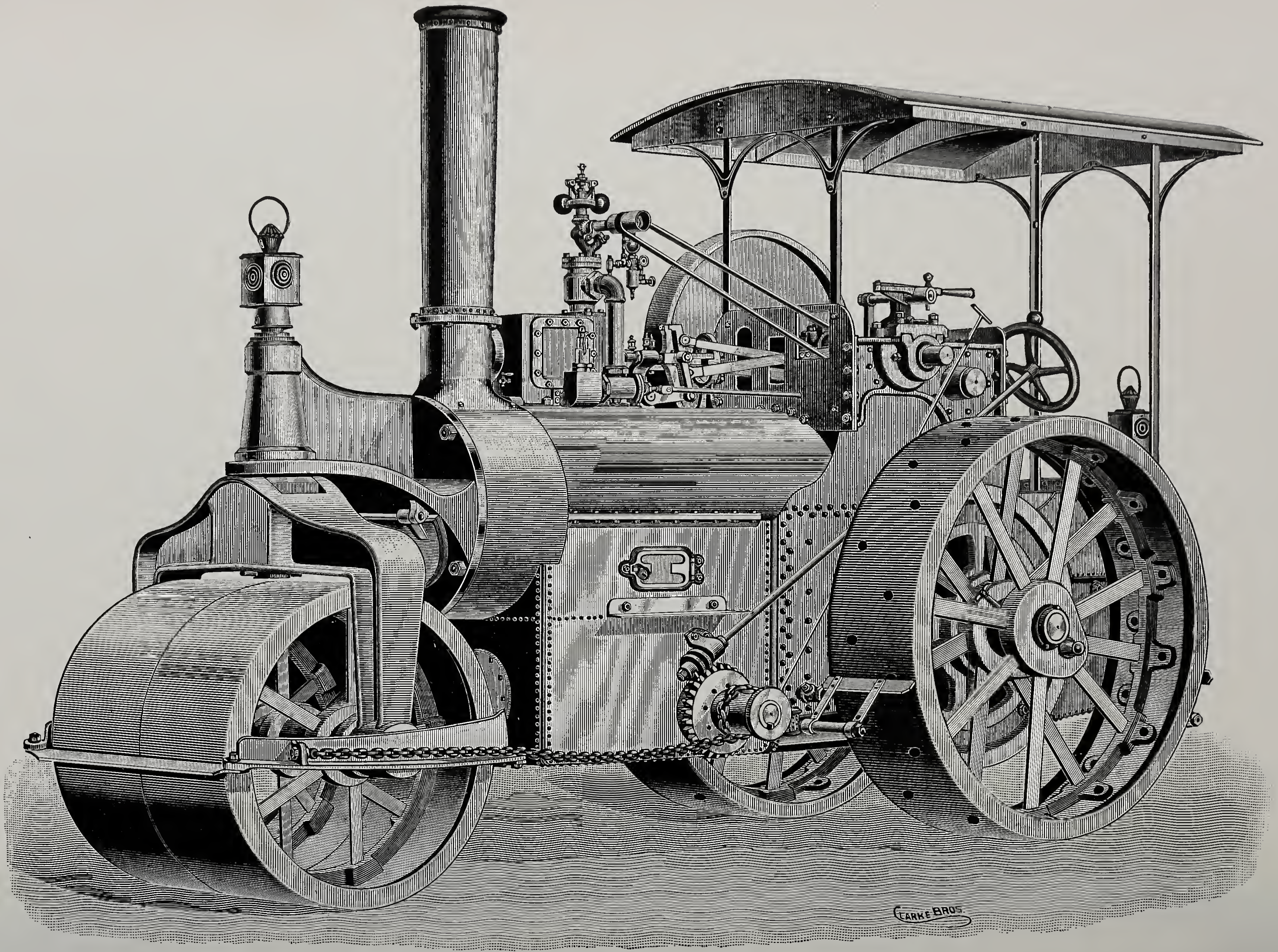
BUST OF HIRAM SIBLEY.

Mr. Hiram Sibley's early days were spent in North Adams, Mass., where he was born on the 6th of February, 1807. After a few years of schooling, before he was 16 years old, he was apprenticed to a shoemaker. The trade, however, was distasteful to him, and he entered a cotton factory, and subsequently tried wool-carding and machine work. In 1853, after a number of successful business ventures on his own account, he was elected sheriff of Monroe county, N. Y. After Prof. Morse had put up his first practically operative line, other inventors took up the work, and soon many telegraph companies were established all over the country. Mr. Sibley consolidated these rival interests, and founded the Western Union Telegraph Company, of which he held the presidency for sixteen years. His next great achievement was the erection of a telegraph line to San Francisco from the Eastern States. His other business ventures were of much importance also. In Illinois he owned a farm of 40,000 acres. He was the proprietor of a most extensive seed and nursery business at Rochester, N. Y., which was his home during most of his life. Mr. Sibley was one of the incorporators of Cornell University, and one of its chief benefactors. He died at his home in Rochester, July 12, 1888.

"The world honors men who have inaugurated great enterprises; it doubly honors men who have made great beginnings of grand social movements." It was in these words that Dr. R. H. Thurston referred to the founder of Sibley College, Mr. Hiram Sibley, upon the occasion of the unveiling of a bust of Mr. Sibley in the chapel of Cornell University, on the 15th of June last.

When Ezra Cornell called his old antagonist in business, become his best friend, into the board of trustees of Cornell University, Mr. Sibley saw his opportunity and promptly seized it. He took as his share of the work the foundation of the Sibley College of Mechanical Engineering and Mechanic Arts. He stepped into the place of honor, and accepted those duties which the State had failed to perform; and Sibley College became the root and sustaining trunk of an enterprise of such importance and of such possibilities as even the wise man who founded it little realized, even though before his death he had the pleasure of witnessing its first great expansion. But it would be an error to suppose that Mr. Sibley's work and munificence were confined to the departure which bears his name. When, at the time of Mr. Cornell's death, it was necessary for the university to secure a loan of $250,000 on security, which at that time seemed very doubtful, though it was in the midst of one of the worst financial crises which has ever occurred in this country Mr. Sibley left his own business, came to Ithaca, and was one of the small number of trustees who advanced the sum which disentangled the finances of the university from their troublesome connection with the treasury of the state, and thus began the real prosperity of the institution. To the close of his life Mr. Sibley remained to Cornell University a true friend, a liberal benefactor, a wise counselor.

Mr. MacNeil, who modeled the bust of Hiram Sibley, is a graduate of the Boston Normal School of Fine Arts, and a former instructor in the art department of Sibley College, Cornell University. He is now engaged in modeling for the art department of the World's Columbian Exposition.



STEAM ROAD ROLLER, MANUFACTURED BY THE O. S. KELLY CO., SPRINGFIELD, OHIO.

ROADS AND ROAD ROLLERS.

EVER since mankind became distributed over countries, roads have become necessary. Since the time of Moses there have been royal roads; first the Egyptians, afterwards the Israelites, then the Greeks called their lines of travel royal roads, or the king's highway.

The Carthagenians were, however, the first to build paved roads, the Romans following their example with the most renowned and durable ever constructed. These were divided into military and local thoroughfares; the first to facilitate the movement of their immense armies, and to connect Rome with all the principal cities and strategic points; the second were the routes of commerce connecting the towns and trade centers, being purposely constructed to facilitate the relations and intercourse of traffic.

These highways were constructed as follows: The road-bed was excavated, the subsoil pounded till firm, piles driven in boggy places, or logs placed crosswise; on this prepared subsoil a layer of large stones, sometimes united with mortar, over this a layer of plaster composed of stone or brick with mortar, this being followed by another layer of sand and lime or sand and earthenware clay, which, like its predecessors, was pounded and leveled with great force. The top was made of irregular stone united with cement, and shaped to form a pronounced curve between strongly made curbs, which at regular intervals were elevated to serve as stiles for the mounting or dismounting of horses. All roads were also supplied with mile-posts.

It is a curious tribute to the skill and intelligence of the Romans that in locating their Alpine roads they followed precisely the methods recognized as best by road-builders at the present time. They seldom, and only in case of need, built a road far down on a mountain side. They followed the sunny side of mountains, accommodated themselves to the lay of the land, and avoided great valley crossings. These judiciously laid-out roads coincide in the main with the leading railway or post routes of the present day.

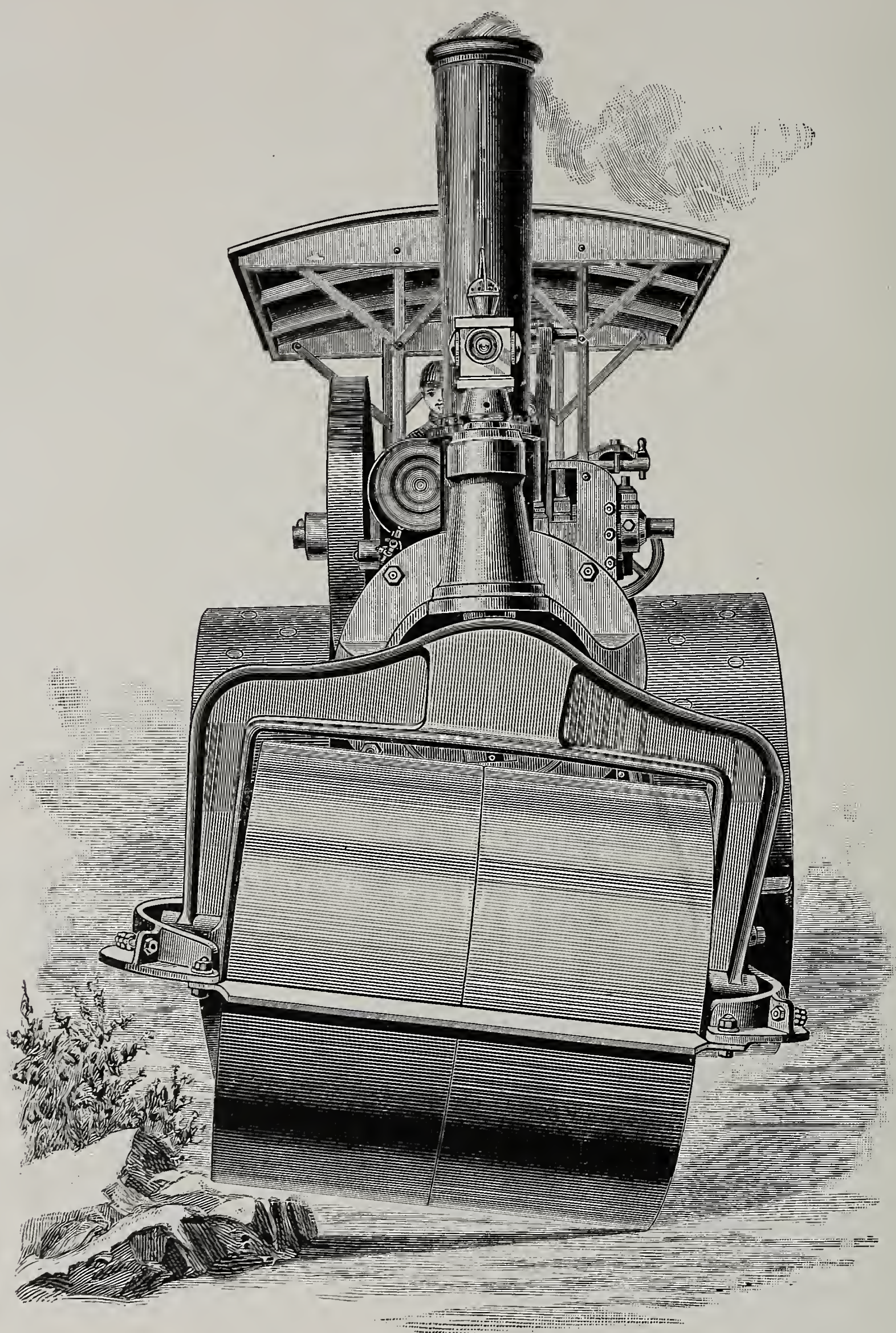
For nearly 2000 years these roads served as the means of international communication between France, Germany, and Italy, no great changes or additions to them being made up to the eighteenth century, when a systematic effort was begun to put them in a state of repair.

After the Romans were driven from France there is nothing to note on the subject of roads until the time of Louis XIV., who had several fine roads made in the environs of Paris for his personal use and pleasure. These were very wide, and paved only in the center for the royal coaches. Soon after the French people began to appreciate the advantage of paved streets, as the use of vehicles was becoming more general, and the commencement of the magnificent network of public roads now covering the whole of France was then begun. The modern road system of France was inaugurated by the first Napoleon, and brought to its splendid conclusion by the late Emperor Napoleon the Third.

About a century ago John Louden Macadam inaugurated a new system of road-making and road-repairing. His leading principle was that a road should be an artificial flooring, so strong and even as to let the strongest vehicle pass over it without impediment. Another principle was that the native soil when dry was more resistant than when wet, and that as it had to carry the road as well as the traffic it should be kept in its condition of greatest resistance, *i. e.*, dry. The best way of keeping it dry was to put over it a covering impervious to rain,—the road in fact; and that the thickness of this covering should be regulated solely in relation to its imperviousness, and not at all as to its bearing of weight, to which the native soil was quite equal. Instead of excavating the native soil he raised the road above it

sufficiently to let the water run off. Impermeability he obtained by the practical discovery that stones broken small and pressed together by the traffic of vehicles rapidly settled down face to face and angle with angle, making as close a mass as a wall. This important discovery has given to us the verb "to macadamize" (to pave a road with small broken stones).

Even in the breaking of stone he made a revolution. He made his stone-breakers sit, so that all the force of the blows took direct effect, he seeing that if a man stood up the greater portion of the force of the blow was lost. The size



FRONT VIEW OF ROLLER, SHOWING POSITION IN PASSING OBSTRUCTION ON THE LEFT.

of the broken stone he determined in a practical way by the area of contact of an ordinary wheel with a smooth road. This he found to be an inch lengthwise, and therefore he laid it down that a stone which exceeds an inch in any of its dimensions is mischievous, for the wheel pressing on one end of it tends to lift the other end up out of the road. He allowed no large stones, for he found that they constantly worked upwards by the pressure and vibration of traffic.

In constructing a new road he usually did it in "three times." He first placed a layer of broken stone 4 inches thick, which was worked till set. Another 4-inch layer followed, and in turn worked till it was set, when the last layer was added. The favorite kind of stone used by him was whinstone, followed by flint, limestone, and pebbles.

The most important quality in stone for road-making is toughness. Hard stone without toughness is ground to powder by the action of the wheels. Limestones, generally speaking, are to be avoided, because of their great affinity for water, which causes them in frosty weather, which has been preceded by wet, to split up into a pulverulent state, destroying the road.

Macadam considered 10 inches of well-consolidated stone enough for any traffic. Experience has proven this to be true in well-drained or well-kept roads, even in London.

Telford and Macadam, while coincident in their aims, were divergent as to methods. Telford held to the use of a bottoming of more or less symmetrically shaped stones set in the form of a rough pavement, forming a substantial foundation for the broken stone to rest upon. Both, however, insisted upon thorough drainage of the subsoil, and both made use of materials broken to gage, both made the curvature just sufficient to shed the rain-water freely to the sides. Telford's description is quoted :

"This foundation is a regular close pavement of stones, carefully set and varying in height from 8 to 5 inches to suit curvature of road. These stones are set with their broadest side lowest, so as to rest perfectly firm, and care is taken that no stone is broader than 4 or 5 inches. The pavement thus made is quite firm and immovable, and forms a complete separation between the substratum of broken stones and the retentive soil below." The French engineer Tresaguet's mode, described in 1764, shows great similarity. Mr. Codrington, a celebrated road engineer, is of opinion that where the bottom is soft and wet, and cannot be well drained, a bottom pavement is most useful. The convexity of surface may be made in the road-bed or the coating.

Telford's practice was to make the road-bed level, and thin the metaling on both sides of the center. Making the roads weaker at the sides is, however, of doubtful utility. A new road should have the road-bed shaped to obtain the desired curve and admit a uniform thickness of metaling. The use of a binding material was not allowed by Macadam, but the proper use of it is founded on reason. It should be applied after the stone is consolidated, and not mixed with it. Sharp sand or road sweepings may be used.

As to the necessity of the paved Telford foundation, engineers are divided in opinion, though the majority decide in favor of Telford, and contend that a good road should have a Telford foundation and a Macadam superstructure.

The cost of the Telford foundation is to a certain extent prohibitory, and many roads are made without it. Very thin roads (only 4 inches thick) have been made to answer perfectly, and under heavy traffic are as easily and cheaply maintained as the much more expensive Telford road. A thicker road, undoubtedly, will last longer, but it costs more in proportion to its thickness.

The key to success in thin road-building is :

First—Thorough consolidation of subsoil by heavy rolling before the broken stone is applied.

Second—Clean binding, which should offer as great resistance to crushing as the stone itself.

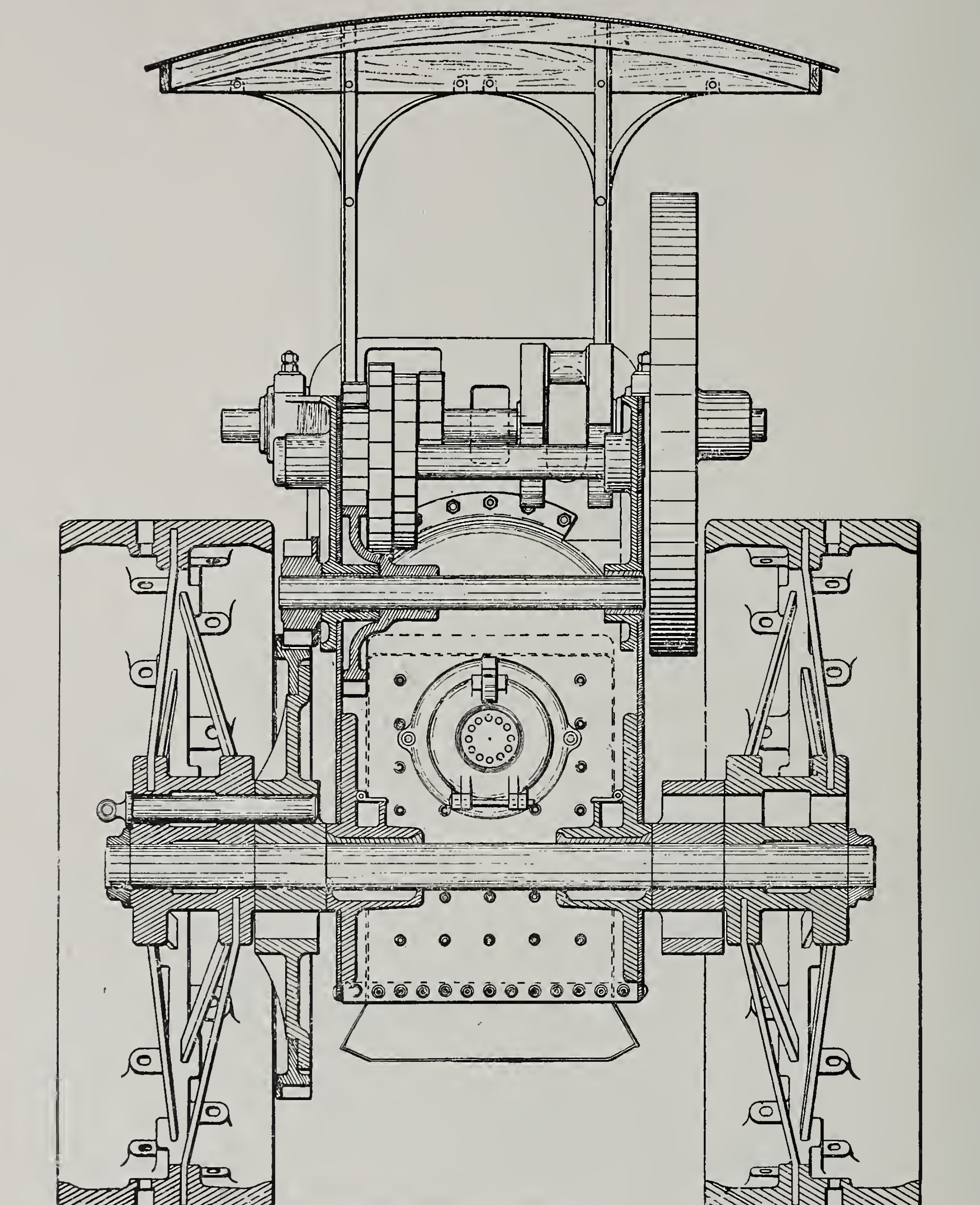
Third—The use of heavy steam rollers.

Fourth—Hard and tough stone, uniformly broken.

The most important auxiliary to good

road-making, and by many engineers deemed absolutely essential, was supplied by M. Poloncean in 1834 by the introduction of the steam roller. Formerly a road was opened to traffic immediately the broken stones were put on; but this was inconvenient, and caused heavy rollers, drawn by horses, to be used to compress and consolidate the material. The loose stones were much displaced by the horses' feet in consequence of the great exertion necessary to draw the roller.

The first English steam roller was manufactured in Birmingham in 1864 by Mr. Wordsdell, from designs by Clark & Baltho, for the municipality of Calcutta. Messrs. Manning, Wardel & Co., of Leeds, England, in 1868 started to manufacture the French Ballaison steam roller, and at about this same period Messrs. Aveling & Porter, traction engine builders, of Rochester, England, made a steam roller for the city authorities of Liverpool. This machine was constructed under the Clark & Baltho patent, in combination with the ordinary traction engine as generally built in England at that time. The "picking-up" device is an earlier in-



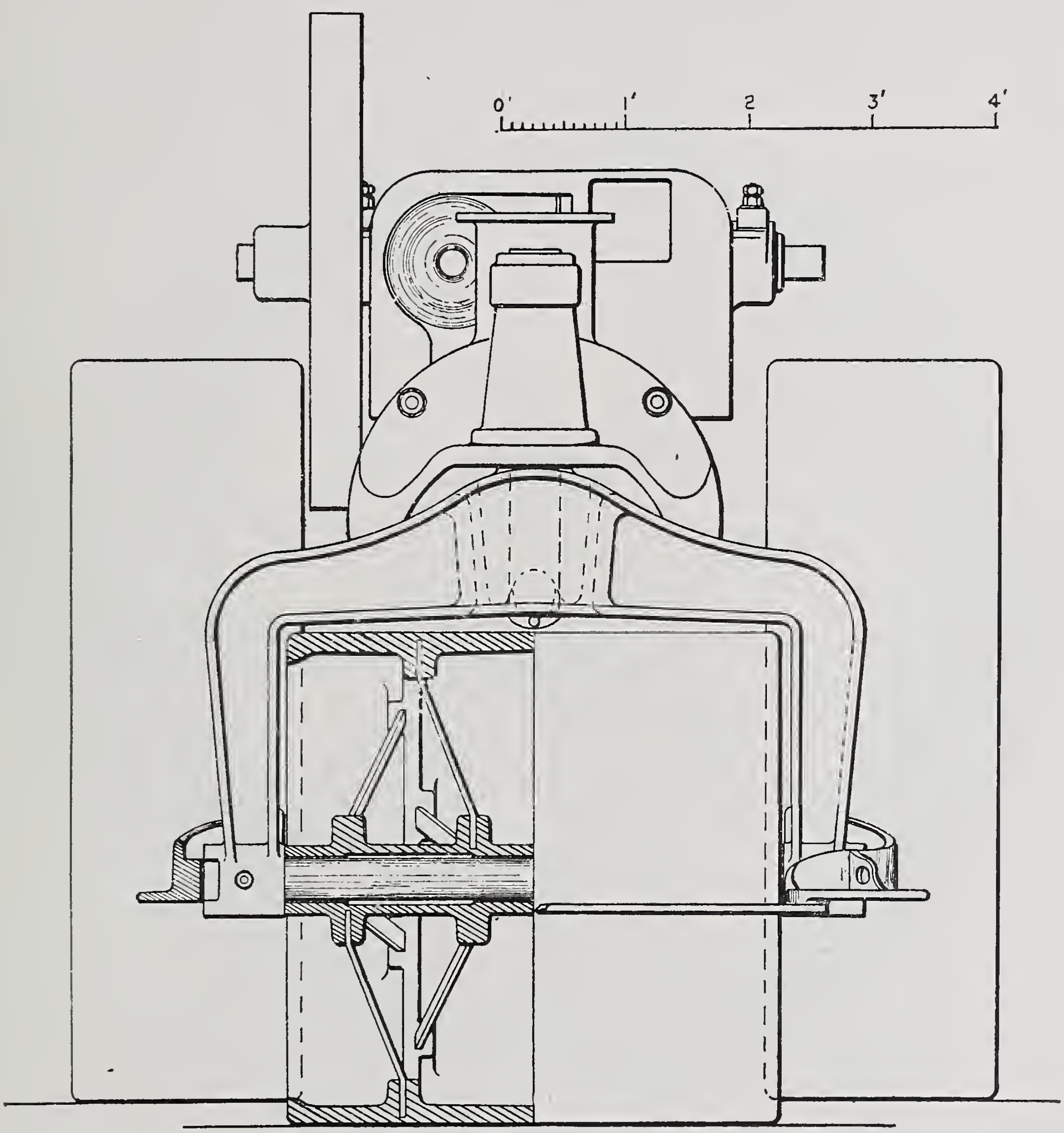
SECTIONAL VIEW OF ROLLER, SHOWING DETAILS OF CONSTRUCTION.

vention of Mr. Browse, of the Metropolis Roads Office, London. During the year 1870 an American machine, known as the "Lindelof," was introduced, and has since been manufactured for the Barber Asphalt Company. This machine is unique in design, has double cylinders, and is especially adapted for rolling plastic pavements.

Steam rolling has proven to be so satisfactory and economical that although it is of comparatively recent introduction, yet there are already several types of steam rollers built in America which in competitive tests have demonstrated their efficiency. One of these machines is built by the O. S. Kelly Co., of Springfield, Ohio. It is designed for road-making in all its details: that is, rolling, plowing, breaking up top surfaces of old, worn-out roads, rolling and consolidating the subsoil, as well as the driving stone crushers.

As will be seen in the accompanying engravings, the rollers are made large and heavy, which allows them to roll much easier, and not crowd the material ahead in the form of a wave, and having more bearing surface on the ground are not so apt to sink in soft places. Large and wide rollers, having more wearing surface and making fewer revolutions, wear slower on both axle and periphery, and also require less power to drive them over obstacles. Heavy rollers, moreover, absorb the sudden shocks received when traveling over rough ground.

The driving wheels have wide and smooth faces, and the space left between

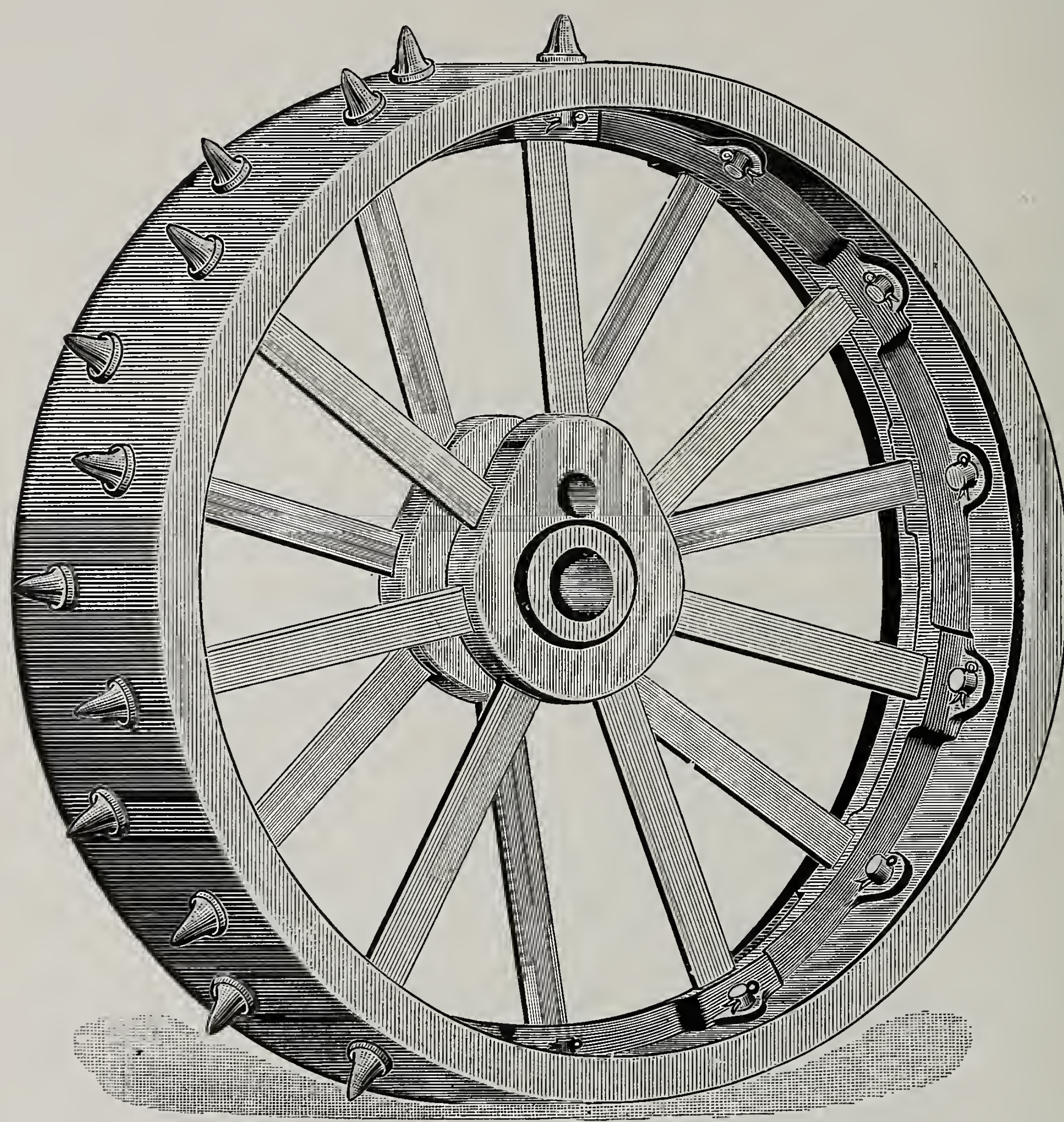


SECTIONAL VIEW OF FRONT ROLLER, SHOWING DETAILS OF CONSTRUCTION.

them is covered by another pair of wheels, which carry the front part of the machine and also act as steerers. Nothing projects beyond the rims of the rear rollers or driving wheels, so that the machine can roll close up to curbing or any obstruction. As shown in figure below, each driver is pierced with 28 holes, placed zigzag to receive as many spikes for plowing up a road. These project 4½ inches from the face of the wheel. When rolling, the face of the wheels is made smooth by closing the spike-holes with suitable plugs. Both wheels are driven from the main axle; but in order to facilitate making short turns, by drawing out or putting in a pin in either wheel one or both may be driven.

The locomotive type of boiler is employed, with a shell made of ⅜-inch steel. The fire-box plates and tube sheets are of $\frac{5}{16}$ and $\frac{7}{16}$-inch steel respectively, and the fire-box is stayed every 4½ inches with ⅞-inch stay-bolts.

A double pinion is fitted on the crank shaft, which can be entirely disengaged from the intermediate gearing by the simple movement of a lever. This lever has three positions: when pushed as far to the left as it will go, the fast gear is in action; when pushed to the right as far as it will go, the slow gear is in action; when placed in the middle of these two positions, the crank shaft can revolve alone, as it is out of gear. No motion can now be given to the driving wheels, and the crank shaft alone revolving, permits machinery to be driven by a belt from the fly-wheel. Of the two speeds provided for in this machine, one is moderately fast, to facilitate traveling from place to place and to be used on ordinary occasions; the



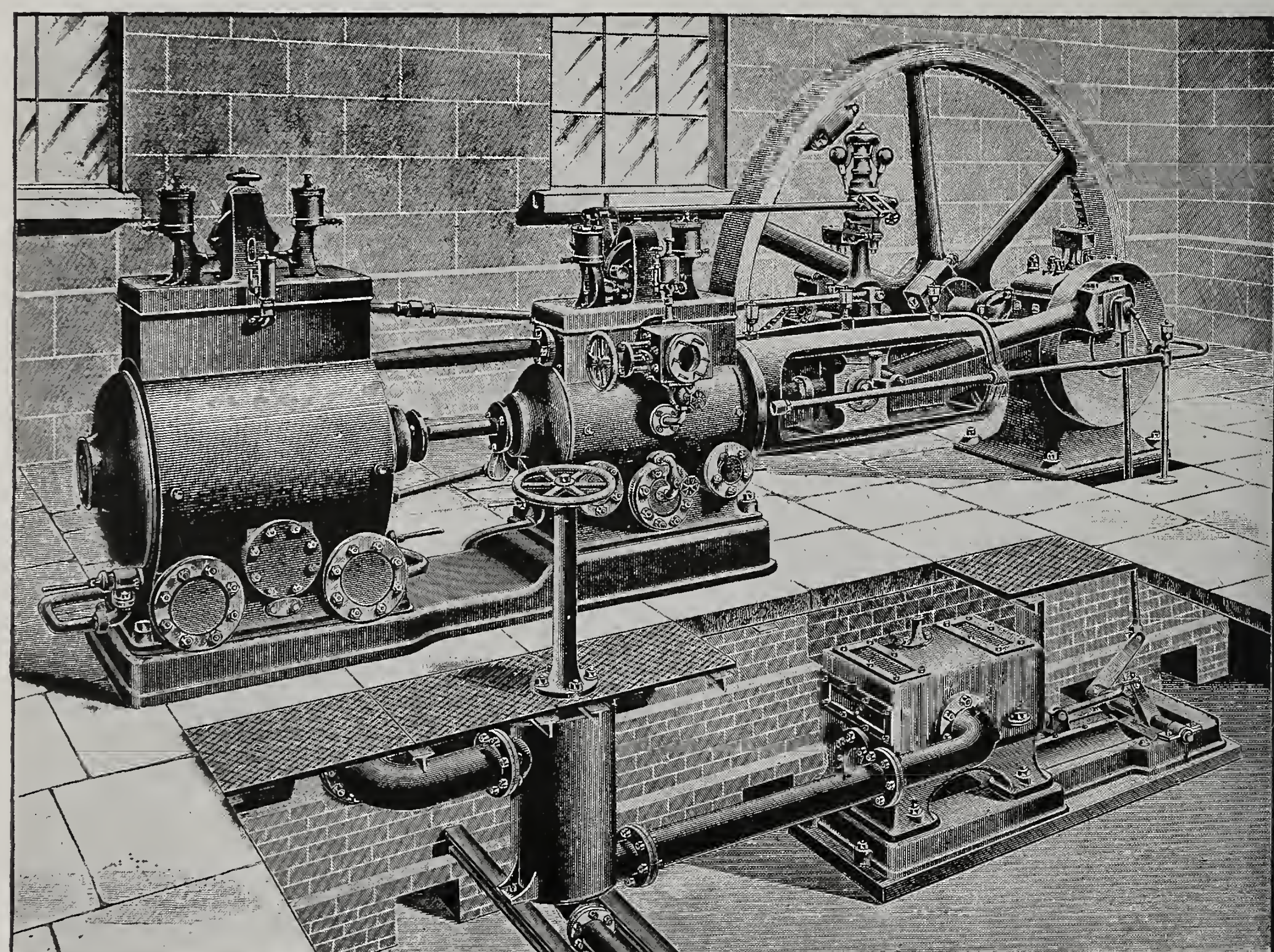
VIEW OF WHEEL, SHOWING SPIKES FOR PLOWING UP ROAD-BEDS.

other, much slower, gives a corresponding increase of power without raising the steam pressure, enabling the machine to work on thick and loose layers of stone, start and work on steep hills, or lift itself out of mud-holes where a single speed roller would probably be unable to extricate itself.

The fore carriage is an entirely new departure in road-roller construction. The smoke-box is fitted with a strong angle iron ring, securely riveted, which stiffens the boiler in the place most needing it. The saddle casting, containing the king-post, fits against this angle iron ring, and is firmly bolted to it. This arrangement increases the depth of the smoke-box, strengthens the end of the boiler, and the faces of both ring and casting being flat, a perfect bearing is made without any internal strain upon the casting. The king-post is of steel cast into the saddle casting; it has no motion, acting only as a center pin for the fore carriage, and is fitted with a swivel-block having concave seats which fit in corresponding convex seats provided in the chamber of the fork. The swivel-block fits snug in the chamber, front and back, but is free to oscillate on its seat sideways in the same chamber; and as the block can swing around the king-post, a swinging as well as an oscillating motion is provided for. This construction permits the machine to steer and accommodate itself to the inequalities of the road.

COMPOUND ENGINE WITH PROELL VALVE GEAR.

THE Proell valve gear has during the last few years undergone considerable alterations and improvements. This gear is here illustrated in its most approved form, as applied to engines of recent construction. Dr. Proell, the inventor of this valve gear, has obtained the co-operation of Messrs. Marshall, Sons & Co. (Limited), of Gainsborough, England, who have taken up its manufacture.



COMPOUND TANDEM ENGINE WITH PROELL VALVE GEAR, BUILT BY MESSRS. MARSHALL, SONS & CO., LIMITED, ENGINEERS, GAINSBOROUGH, ENGLAND.

Referring to drawings it will be seen that formerly a straight double-armed lever T was oscillated through an angle of fourteen degrees, and by means of bell-crank levers K_1 and K_2 alternately depressed and released the valve lifters H^1 and H^2, whereby the valves were opened. The duration of this opening—regulating the point of cut-off—depended on the position in which the governor held the fork N, by which the tail ends of the bell-crank levers were supported, thus determining the overlap, and consequently the period of engagement of the opposing steel faces. In this construction there was still retained, if even in a slight degree, the drawback to which all similar constructions are liable,—viz., that the pressure required to open the valve was liable to react upon the governor, and thereby to throw actual work upon it. The present construction, it will be seen, entirely overcomes this objection in a simple manner. The bell-crank lever (Fig. 2), instead of being made straight, is made in crescent form, and the bell-cranks are provided with shoes S_1 and S_2, which prevent the steel faces from overlap-

ping more than to a very small amount, and which is equal for every degree of cut-off. The shoes S_1 and S_2 rest against ment when its right-hand arm is going down and the bell-crank K_2 is engaging the valve lifter H_2. It will be seen that

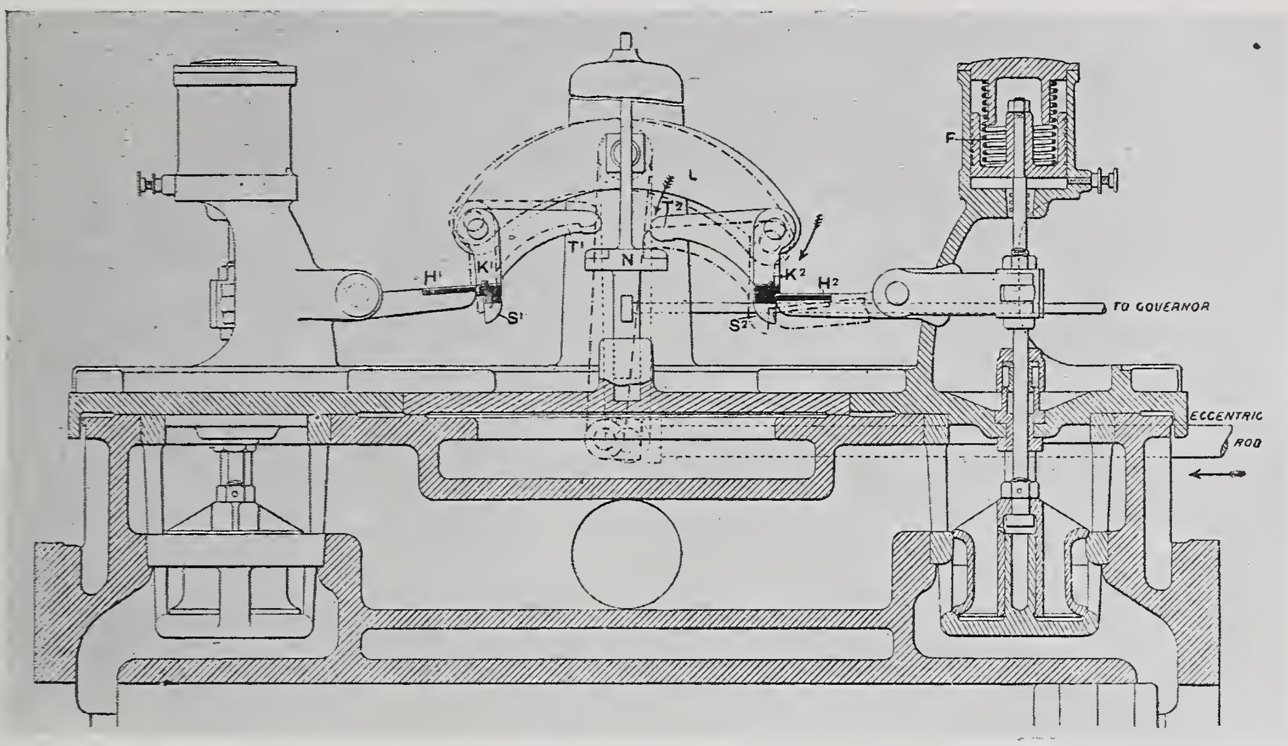


FIG. 2. NEW FORM PROELL VALVE GEAR.

the end of the lifters and prevent the tail ends of the bell-cranks from resting on the tripping pad N, the height of which at this moment the tail end T_2 is some distance off the tripping pad N, and there is, therefore, no possibility that

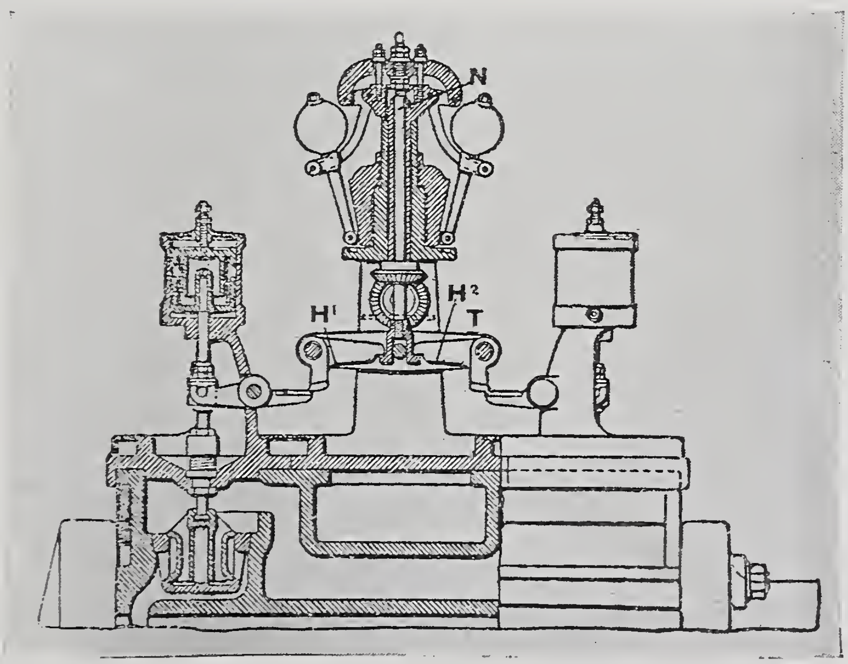
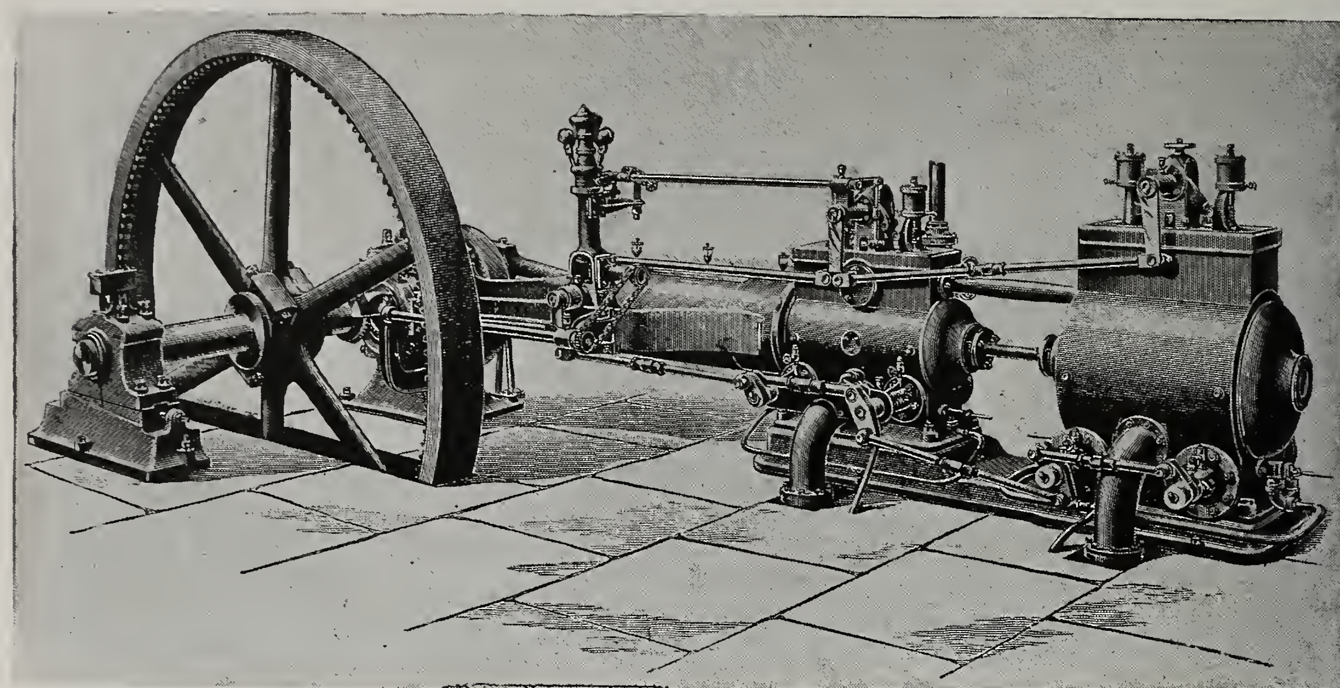


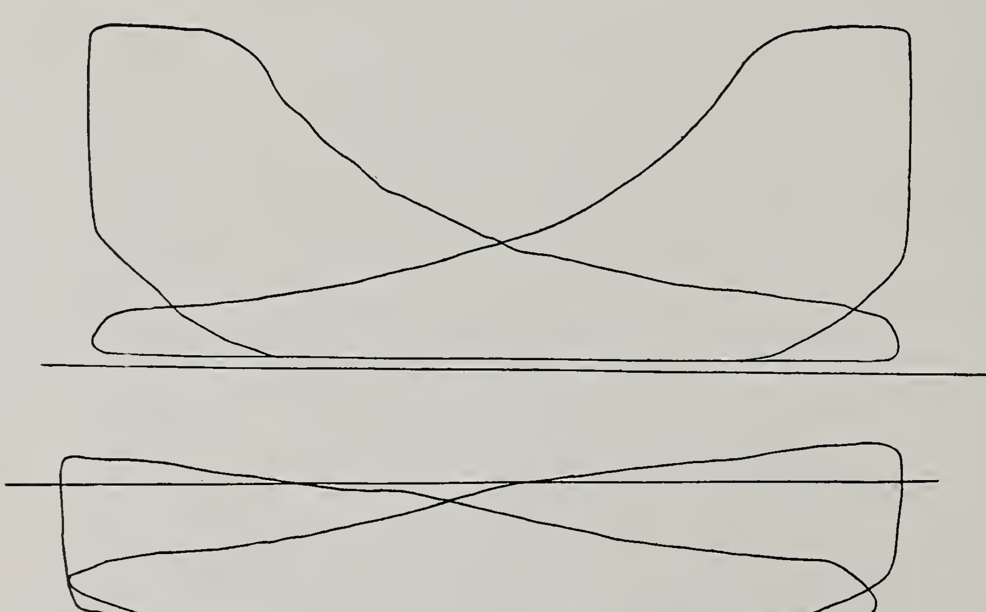
FIG. 3. THE GOVERNOR.

is determined by the governor. The lever L, as shown in full lines in Fig. 2, is in the position it occupies at the mo- the work required for the opening of the valve should act upon the governor. While formerly the wider or

narrower overlap of the steel faces determined the cut-off, and the tail ends were supported by the governor at the opening of the valves, this is now effected by the longer or shorter distance in which the tripping pad is held by the governor away from the tail ends of the bell-cranks. The governor, in fact, comes only into play at the moment when the cut-off is to be effected, and at that time the valve is surrounded by steam, and has only upon it the slight pressure of the closing spring F in the dashpot. The dotted lines of the illustration show the gear at the moment of release of the valve, when the tripping pad prevents the further downward travel of the tail end T_2, and the left-hand bell-crank K_1 has gone into position to open the valve for the return stroke.



COMPOUND TANDEM ENGINE WITH PROELL VALVE GEAR, SHOWING THE VALVE GEAR.



DIAGRAMS TAKEN FROM HIGH- AND LOW- PRESSURE CYLINDERS.

A further improvement lies in the use of the Proell spring governor, in which a strong spiral spring replaces the weight formerly used, which was too limited to allow the use of strong

centrifugal force. The balls are, by a peculiar but simple suspension device, guided so that they open in a straight line instead of an arc, whereby the increase of centrifugal force is always kept commensurate with the increase of spring power. The result of this simple construction is an extremely sensitive, but at the same time powerful, governor. Numerous applications of this governor in connection with the Proell gear have proved, we are informed, that it is capable of controlling engines even under extremely difficult conditions, such as in simultaneously driving saw mills and dynamos for electric-light installations. The governor is fitted with a counter-spring, by means of which the main spring can be supplemented in such a manner that the speed of the engine can be varied ten per cent. faster or slower, as required, while the engine is at work. This counter-spring is, moreover, applied in such a way that its action does not alter the sensitiveness of the governor, as is sometimes the case.

The exhaust of the two cylinders is effected by a simple combination of Corliss valves, and, on its passage from the high to the low-pressure cylinder, the steam is reheated in a jacketed receiver, an operation which accounts for the small loss in pressure shown by the low-pressure diagram.

To *Industries*, London, we are indebted for the illustrations and description of this engine.

THE BRAYTON PETROLEUM ENGINE.

THE progress that is being made by the petroleum engine is very remarkable, and the possibilities of the motor are at present difficult to estimate. The Brayton engine in England has been successfully used for some years in the form shown in the accompanying engravings, but recently its mechanical details have been modified.

The Brayton engine is quite distinct from most other types of hydrocarbon motors, in that no attempt is made to vaporize or even to heat the petroleum spray. The oil is finely divided—atomized, in fact,—in a large quantity of air, and is flashed into flame instantly. The combustion resembles that of flour-dust or coal-dust suspended in the air,

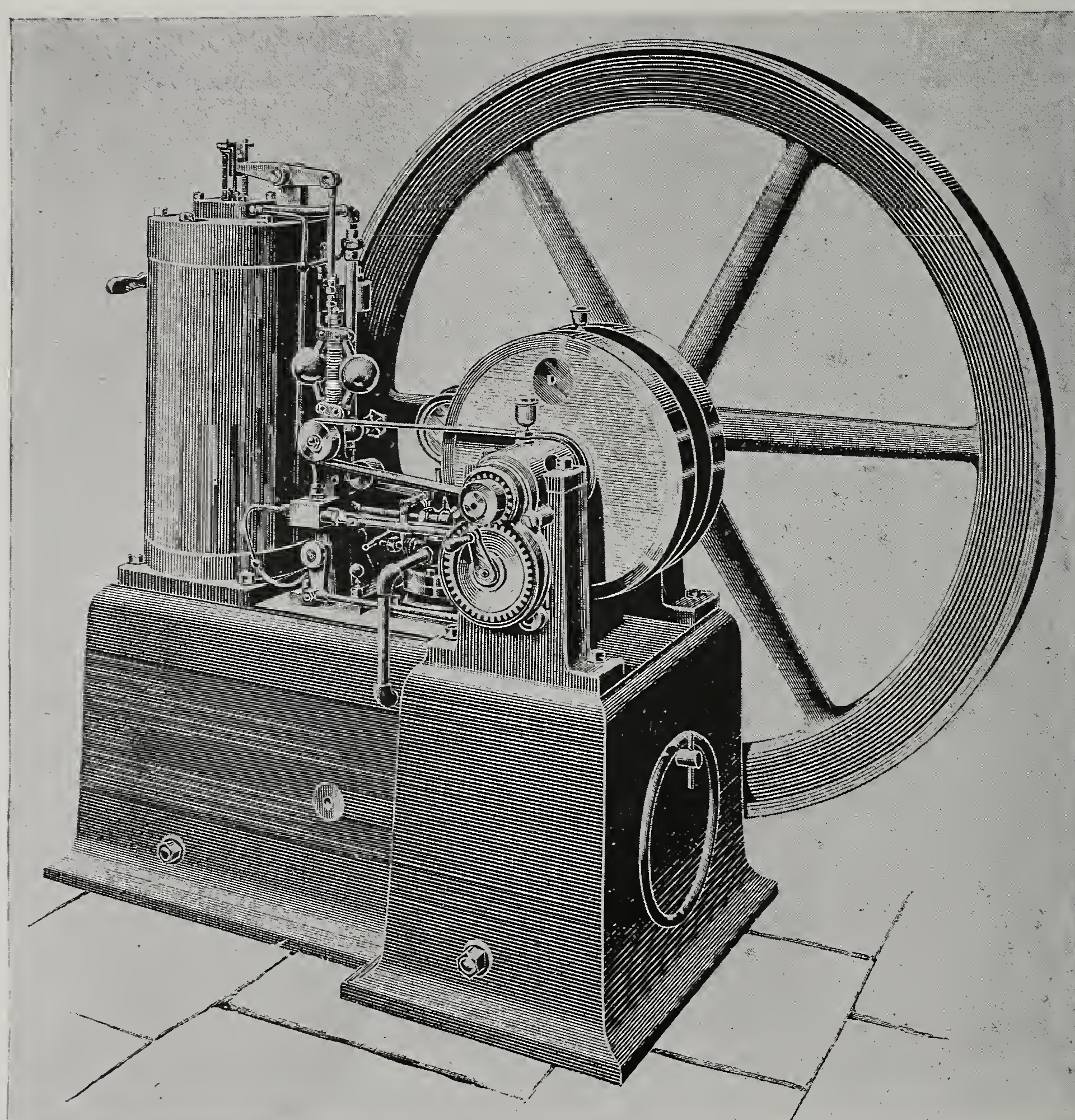
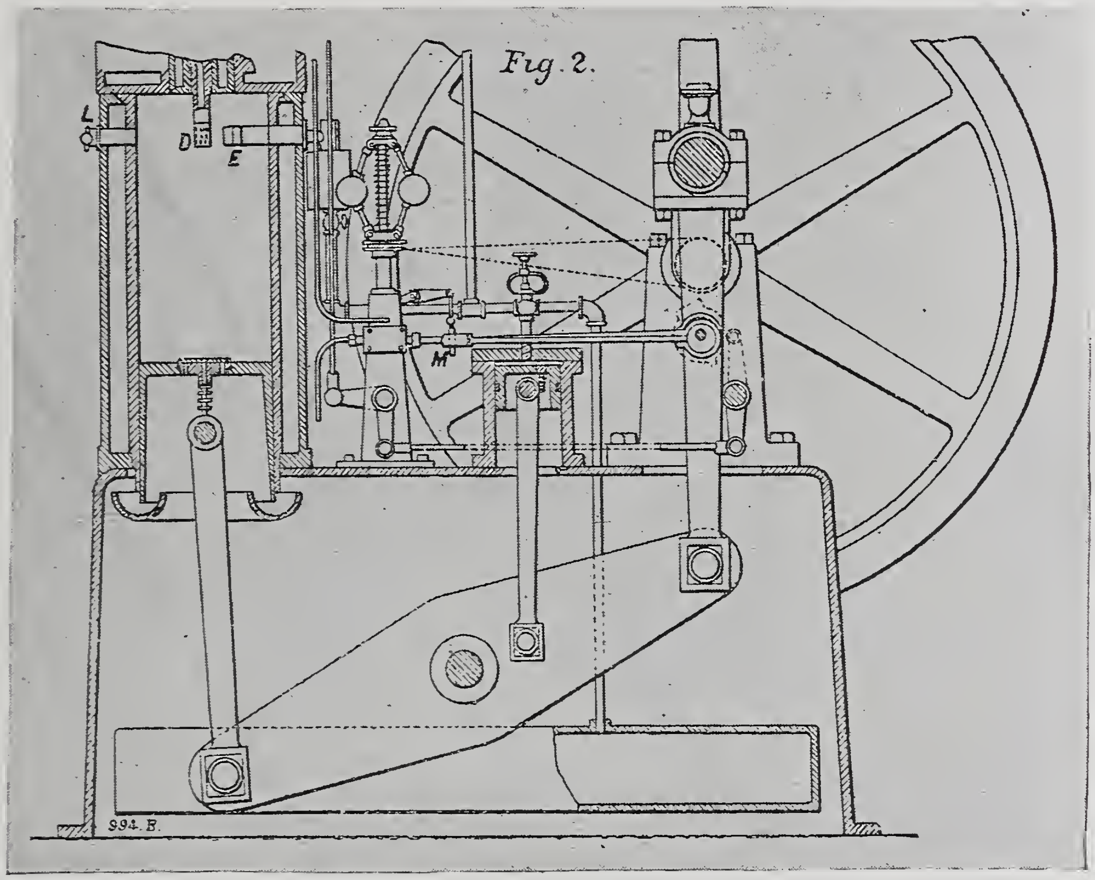


FIG. I. THE BRAYTON PETROLEUM ENGINE.

and it is so rapid that it constitutes an explosion. The combustible material is divided into infinitely small particles, and each particle is surrounded with an ample supply of oxygen, to which it exposes a surface which is very great in relation to its bulk. Under these conditions combustion is exceedingly rapid, and spreads from particle to particle with amazing celerity. The oil is burned suspended in air ; its combustion is complete, and is not impaired or delayed by metallic surfaces on which deposits can accumulate.



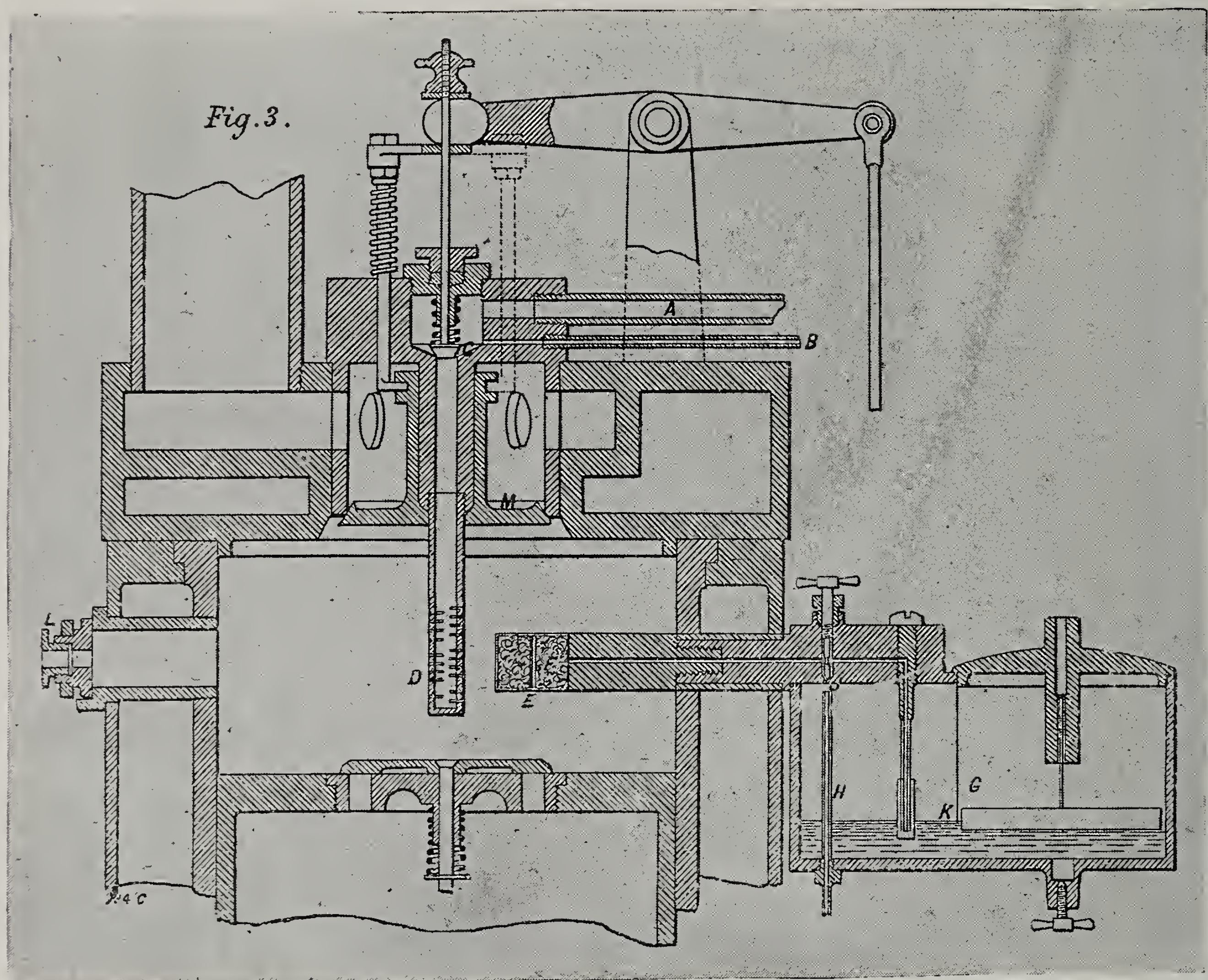
SECTIONAL VIEW OF THE BRAYTON PETROLEUM ENGINE.

The method of ignition is entirely novel. As the oil is not admitted till the moment of explosion, there is no question of "timing" valves, or of attaining a certain degree of compression before the charge can be fired. A brilliantly incandescent surface can be maintained in the cylinder all the time, ready to ignite the first drop of oil that comes in contact with it. To do this advantage is taken of the well-known phenomenon of flameless combustion, which is often shown on the lecture table and but seldom found in practical work. A jet of air laden with hydrocarbon vapor is made to impinge continuously on a coil of platinum wire which has been previously heated, and as long as the jet is continued the platinum is maintained at a glowing temperature within the cylinder.

The engine works on a modification of the Otto cycle. Explosion, exhaust, suction, and compression follow each other in the usual order, but the suction is a suction of air only (not gas and air), and the compression also a compression of air only. Further, the exhaust valve is held open during the early part of the compression stroke to "scavenge" the products of combustion out of clearance space, and to replace them by air. As the oil is sprayed into the compressed air in the cylinder it requires a blast of high-pressure air to effect its entrance. This air is obtained from a pump, which also supplies air to the incandescent burner, a pressure of eighty pounds to the square inch being employed for this purpose.

Having thus set forth the general principles on which the Brayton oil engine works, the details of its mechanical construction, as printed in *Engineering*, will now be explained.

Fig. 1, taken from a photograph, shows it externally; while Fig. 2 is a section taken from the patent drawings, and is partly diagrammatic. Fig. 3 shows some of the details. The general appearance is that of an inverted beam engine, the beam being inclosed within this valve is lifted the oil is driven violently down the pipe, and through the circumferential cuts at its lower end, into the clearance space of the cylinder. The oil is finely divided by the action of the blast, and is driven out at several different levels in minute particles. When we remember that most oil-engine makers claim to work with much less than two grains of oil per horse-power at each explosion, it will be seen how finely the charge may be divided.



SECTIONAL VIEW OF THE BRAYTON PETROLEUM ENGINE.

the bed (Fig. 2), and having a connecting rod at each end of it. From an intermediate point in the beam there is worked the small pump which supplies the compressed air for spraying the charge and for maintaining the firing light. This pump is connected by a pipe to the cylinder head, shown to an enlarged scale in Fig. 3. This pipe *A*, together with the oil supply pipe *B*, discharges into a chamber, the bottom of which is closed by a valve *C*. When

The igniting device *E* is placed near to the sprayer *D*. The former consists of a tube, in the end of which there are coils of platinum wire. These are separated from a packing of asbestos *F* by a perforated steel disk and a plate of wire gauze. A fine bore tube connects the firing device with the auxiliary oil reservoir *G*, in which the oil is kept at a constant level by a float. Air from the pump is admitted to this reservoir by the pipe *H*; part of it goes direct to the

platinum burner through the adjustable cock *J*, and part through the device *K*. This latter consists of a perforated vessel having an internal pipe, the lip of which is below the oil level, so that oil and air are driven upon it in spray to the asbestos pad *F*. The heat of the cylinder continually vaporizes the petroleum in the asbestos, and insures it being carried forward in gaseous form to the platinum coils. In order to effect the preliminary heating of the platinum there is provided opposite to it a door *L* with a glass-covered aperture in its center. This door is opened, and a torch inserted by which the platinum is raised to a red heat.

The oil pump *M* (Fig. 2) is operated by an eccentric driven by one to two gearing from the crank shaft. The exact length of stroke of this pump is determined by a wedge, which occupies a position in a slot between the ends of the eccentric rod and of the pump plunger. When the engine is running above the normal speed the wedge is raised by the governor, and there is a large amount of lost motion ; when it is running below the normal the wedge is lowered, the stroke of the pump is nearly equal to that of the eccentric. A hand crank is provided (Fig. 1) by which the pump can be worked before the engine is started. On the same shaft with the eccentric is a cam for operating the oil inlet valve *C*, and the exhaust valve *M*, the former being opened when the left-hand end of the level above it is raised, and the latter when it is depressed. The exhaust valve, as already stated, is opened at each revolution.

It first evacuates the greater part of the products of combustion, and next it allows part of the air to blow through to scavenge the clearance space. This air is admitted by an automatic valve in the piston (Figs. 2 and 3), which opens as soon as a partial vacuum is formed in the cylinder, This position is chosen for the valve because the air can enter with little disturbance of the hot products of combustion, which congregate above, and can then sweep them completely out of the cylinder.

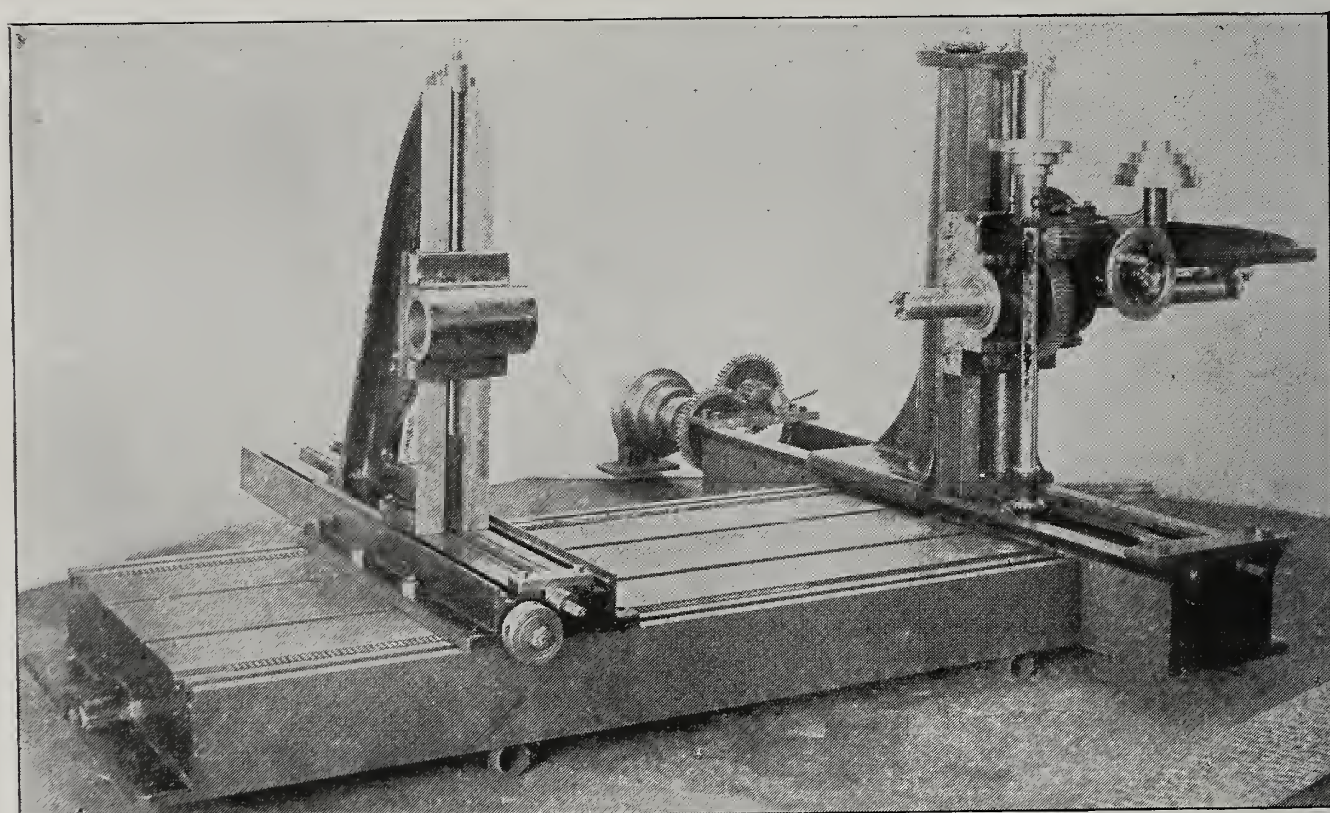
To start the engine, the door *L* is opened and a torch of asbestos in paraffin is introduced and placed beneath the burner *E*. When this is properly heated the torch is withdrawn and the door closed. A charge of oil is then injected by hand and the fly-wheel turned. On the compression stroke an explosion should occur, after which the engine runs without further attention. The cylinder is, of course, water-jacketed in the usual way.

For the illustrations and description of this engine we are endebted to *Industries*, London.

NEW MACHINE TOOLS.

THE engravings shown herewith represent some new machine tools which have been placed on the market by Beaman & Smith, Providence, R. I.

The horizontal-spindle drilling and boring machine is intended for drilling or boring work which can be securely fastened to the bed and tools brought to the desired position without the necessity of moving work, which is much more convenient and accurate than the outer bearing moved to correspond. Accuracy of adjustment is secured by four graduated steel rules suitably placed with pointer. The carriage on the platen has a quick adjustment by racks and pinions from the outer end of platen nearly to the spindle, and can be rigidly fastened. The greatest distance from spindle-head to outer bearing is seventy inches. The countershaft has tight and loose pulleys, and should run at 130 revolutions per minute.



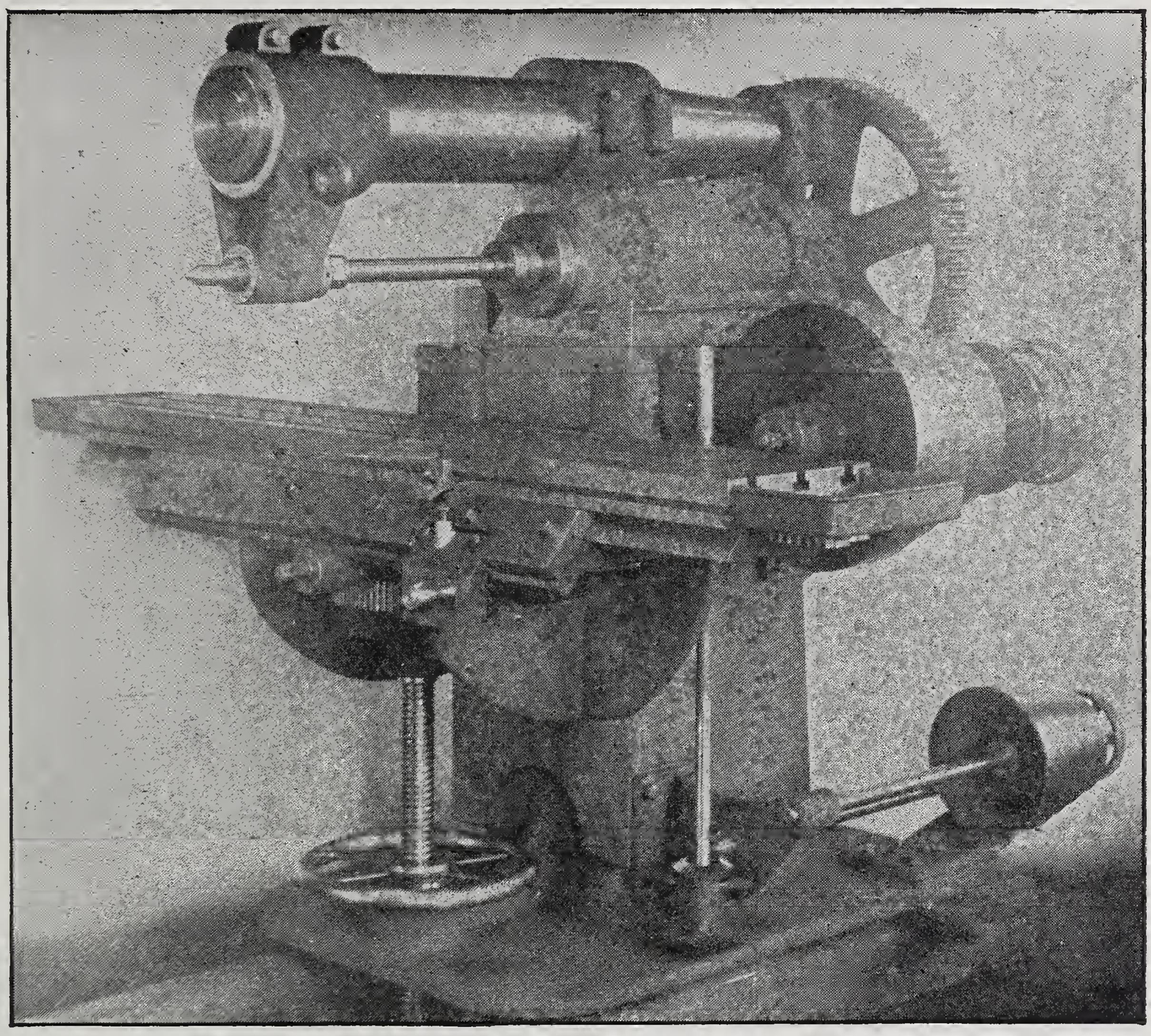
HORIZONTAL-SPINDLE DRILLING AND BORING MACHINE, BUILT BY BEAMAN & SMITH, PROVIDENCE, R. I.

moving the work, particularly where it is heavy. The platen is eight inches high, forty inches wide, eighty-four inches long, is heavy and well ribbed, has seven tee slots seven-eighths inches wide, and to it is securely fastened the bed which supports the upright with spindle. The greatest distance from top of platen to center of spindle is forty inches, the least ten inches. The spindle can be moved vertically thirty inches, horizontally forty inches, and

The milling machine is intended for general machine-shop use, but on larger work requiring larger cutters and taking deeper cuts than usually attempted on milling machines of its type. The head is thirty-two inches long, has a horizontal movement of three inches on top of standard for the cross adjustment of the cutters, thus dispensing with one joint below the table, and has an overhanging arm eight inches in diameter which is removed for the use of cutters

over twelve inches in diameter. The spindle, which is of steel and runs in bronze boxes, has a threaded end for face-cutters and taper-hole for cutter arbors. The table is fourteen inches wide and seventy-two inches long. At the lowest position of the table its top is twenty-four inches below the center of the spindle. The feed is the full length of the table, and is driven by a $2\frac{1}{2}$-inch belt on a four-section cone, and in connection with intermediate gearing twenty changes of feed can be obtained, so that the maximum rate of feed per minute of the table can be maintained irrespective of the diameter of cutter used and proportionate spindle speed.

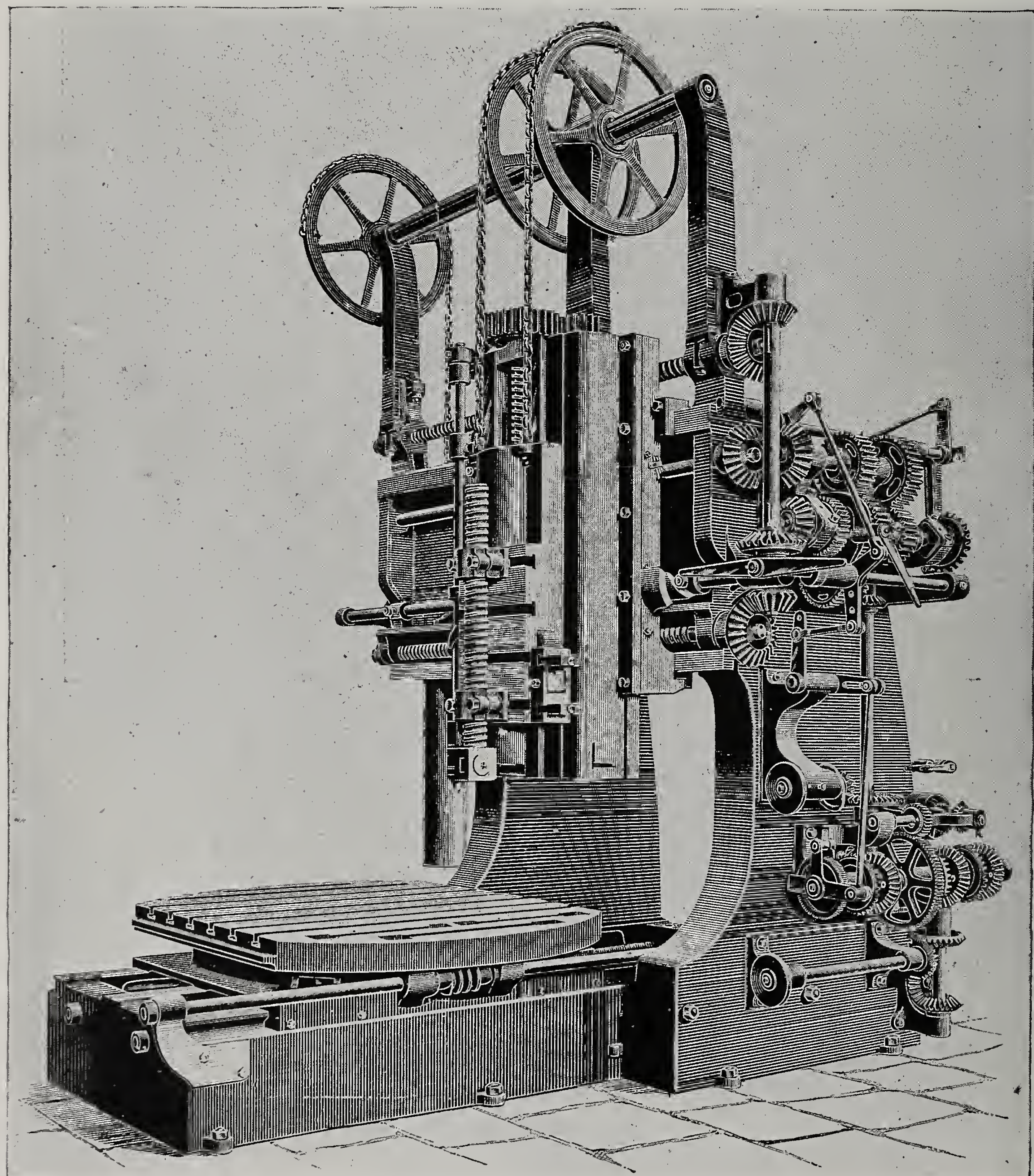
This is a desirable feature, as it is frequently required that the rate of feed per minute of the table should be greater when using a cutter of large diameter and consequently slow spindle speed than when using a cutter of small diameter and fast spindle speed. An automatic vertical feed for the knee can be furnished, also a vertical-spindle milling attachment.



HEAVY STANDARD MILLING MACHINE, BUILT BY BEAMAN & SMITH, PROVIDENCE, R. I.

NEW SLOTTING MACHINE.

THE annexed engraving, taken from *Engineering*, represents a large slotting machine built by Messrs. Thomas Shanks & Company, of Johnstone, near Glasgow. It is a very complete machine, the details being clearly shown in the illustration. The tool weighs thirty tons, and the stroke has been made forty-two inches and forty-eight inches, which stroke is independent of the vertical slide-bed upon which the tool-ram moves. This bed is adjustable vertically thirty inches. The tables are furnished with quick power motion either way, as well as with a variable self-acting feed. The part of the frame which receives the "punching" strain has been cast in one piece without exceeding the limit of dimensions for railway shipment. This is a great advantage over large machines which have the column and the bed bolted together, a plan which in a punching machine would soon prove a failure.



Reflections and Observations.

It has always been a wonder to me that so few business men recognize the consulting or mechanical engineer to be what we would call a "professional man." They all take it for granted, of course, that if they call upon a lawyer they must write their check for a retainer of twenty-five dollars to five hundred dollars. If they stick their tongue out for a physician's examination it costs five to ten, or even fifty dollars.

If, however, their engine doesn't run right, or they wish to enlarge their plant, or in any way need advice, and the professional engineer is called upon and a bill follows—lo and behold! the engineer who has the audacity to think of charging is called a Shylock or a fool.

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What has set me to writing in this strain is a story I heard about the manager of a large corporation who knew a little about mechanics, so that when his engine-runner showed him some cards he had taken from the engine, he (the manager) recognized at once that the engine was in bad condition, but neither of them could tell the cause or recommend a remedy.

"These cards," said the manager, "are simply terrible."

"I know it," said the engineer.

"Well, I'll run down and see my friend Mr. —— about it. He will tell me the cause of the trouble."

So he took a cab (his income warranted such an extravagant expenditure) and called upon his "friend," the consulting engineer.

The cards were left, and a few days later he returned to get the report.

It wasn't type-written. The consulting engineer told him that the valves leaked badly and were not set right. Advised that the builders be called upon to adjust them.

The manager said he thought the same, but wasn't sure. "Much obliged" and "Come and see me some time," etc.

Well, the consulting engineer was a man of business. Had spent three or four hours on the cards, and of course sent in his bill. It was for twenty-five dollars,—very moderate.

But now we come to the story. Meeting a friend at the club who knew the consulting engineer, the manager said:

"You know Mr. ——, don't you?"

"Why yes; dined with him a number of times. Deuced clever fellow, you know."

"Well," replied the manager, "I don't think so. I believe he's a fool."

"What makes you think so?" asked my friend in surprise.

"I don't think so, I know it. I went up to see him the other day and asked him about my engine, and the day after he told me in comes a bill for twenty-five dollars for professional services. Would any decent man think of doing that? Of course not."

"I agree with you," replied my friend. "He is a fool, or he would have sent in a bill for one hundred dollars."

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"There is something peculiar about manufactured ice," said a gentleman to the writer the other day.

"What do you mean?" I asked.

"Well, I find that I get remarkably strong by handling it," he replied.

"Do you mean it gives you strength?"

"Yes; and I have been wondering if it is the ammonia, or the compressed air, or something."

I became interested, for it was a new

idea ; in fact, I had never heard of it before.

"Won't you explain yourself?" I asked.

"Well," he replied, "the ice man left me 300 pounds of manufactured ice the other morning, and five minutes after I went out with a pair of tongs and put it in the refrigerator. It's very strange, for I couldn't lift over twenty-five pounds of anything else. How do you account for it?"

I have no doubt a number of my readers can tell.

THE story is told about a colored man who wanted to get a job for his boy, a pickaninny of eight years of age.

Coming into a machine shop at Richmond, Va., and seeing a young man at work at a lathe, he apparently got an idea that the labor of building engines was very simple.

"What sort of a job do you want for the 'kid'?" asked the foreman.

"Oh, it doan matter much ; anyting will do."

"Well, what can he do?"

"Well, at fust," he replied, "I doan tink he could do much beside makin' injines, but bimeby when he growed up and made more sense I tink he could black yer boots and sweep up de flo'."

I WENT down with a friend to Manhattan Beach one hot day last week, and having become quite used to the peculiarities of a big crowd at a big hotel we found a vacant place, and made ourselves comfortable for a lengthy stay.

Of course, if we had been hungry we would have perhaps died of starvation by the time the dinner was served, but we came prepared, as I have said.

Some people expect to pay fifteen or twenty dollars and get a meal as good as they would at home ; but alas ! they soon find that they have made a great mistake.

A man dining at the next table to ours kept up a steady "kick" at everything he had served to him.

This was too hot. That was too cold. The steak was tough and the potatoes were raw. The waiter didn't know anything.

At last he was ready for his check, and as he was adding it up he said :

"It's robbery ! Two dollars for that steak, and it was ice-cold besides !"

"You could have had it hot," politely replied the waiter, "by paying fifty cents more."

"Why should you charge more for serving it hot," asked the kicker.

"Well, you know," replied the waiter, "everything expands with heat."

THE OBSERVER.

C. J. H. Woodbury.

CASSIER'S MAGAZINE.

VOL. II. SEPTEMBER, 1892. NO. 11.

THE "NORWOOD" MAKING A MILE IN 2 1-5 MINUTES.

SOME FAST STEAM YACHTS.

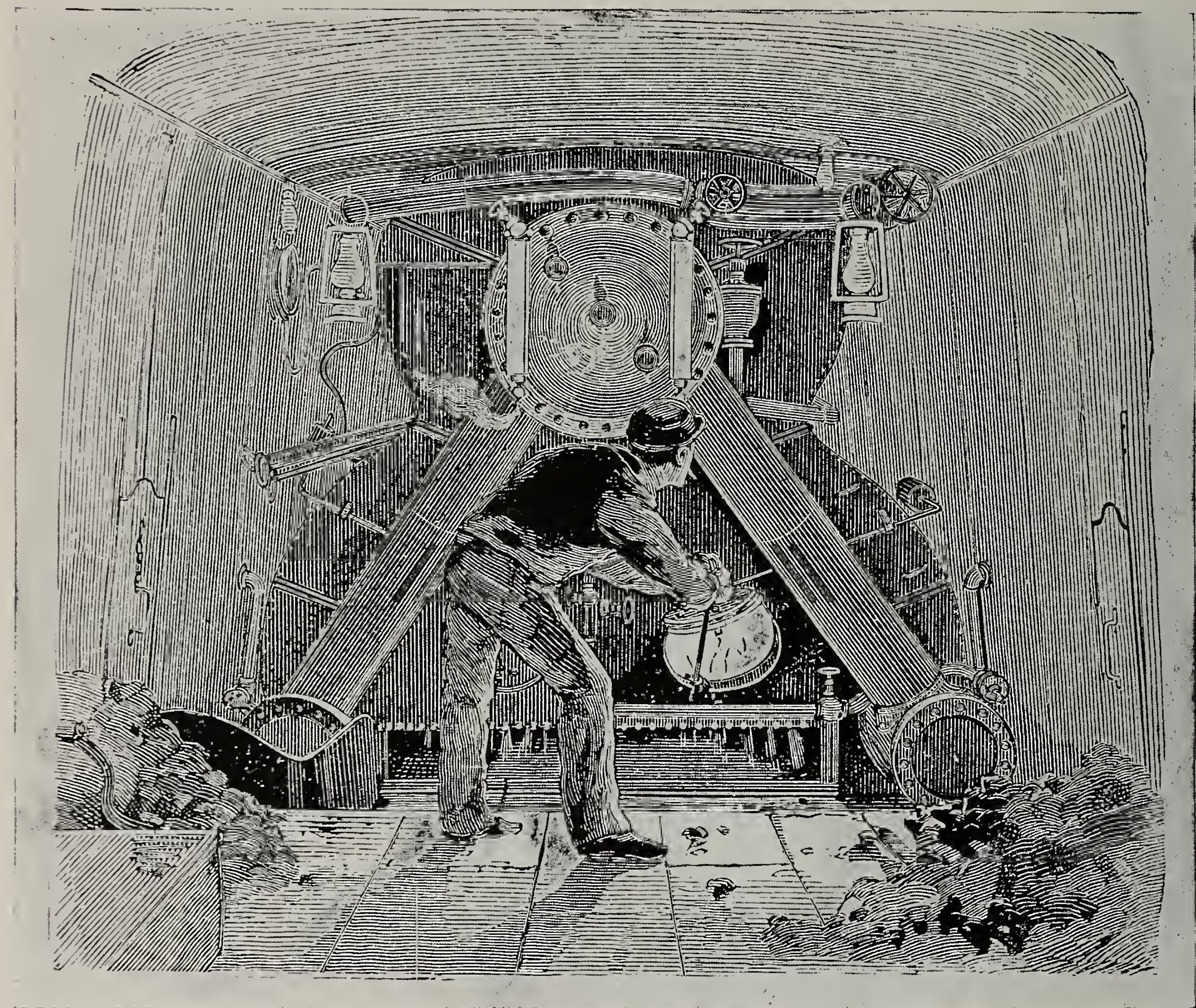
By Charles H. Werner.

THE general prosperity of the closing years of the nineteenth century is in no way better displayed than in the numerous steam yachts built for the pleasure and comfort of man. There are more magnificent sea-going ships and racing vessels to be seen in New York harbor to-day than in any other part of the world, and the New York Yacht Club numbers among its fleet of steam yachts some which excite the envy of kings, while all the other clubs about the city and Long Island Sound also have a number of magnificent craft. The majority of these boats, however, are not extravagantly built, varying in size from 40 to 70 feet, very few of them running over 100 feet. These yachts are used principally as private ferries, bringing their owners to and fro from their surburban homes to the city in the morning and returning in the afternoon.

Aside from these boats, there is another type built exclusively for speed. The recent discussion among engineers regarding the relative merits of the *Norwood* and *Vamoose*, and later still the challenge to the owners of the *Yankee Doodle*, have served to increase the interest in high-speed yachts. These three vessels, together with the *Now*

Then, of which little has been said lately, are probably the fastest steam yachts afloat, and the illustrations printed give a fair idea of their character. The *Vamoose* and the *Now Then* were originally built by the Herreshoff Manufacturing Company, at Bristol, R. I., while the two others mentioned were built by Mr. C. D. Mosher, of New York, formerly of Amesbury, Mass. The *Now Then* is a closed boat, which was originally constructed by the Herreshoffs for Mr. Norman L. Munro, the New York publisher, but after various changes in ownership finally came into the possession of Mr. J. Edward Addicks.

The *Now Then* is 81 feet long at the water line and has a draft of 38 inches, and has inverted direct-acting triple-expansion engines. The cylinders are 7½ inches, 12 inches, and 19 inches in diameter respectively, and the stroke is 10½ inches. She has an inboard surface condenser. She is fitted with a Mosher water-tube boiler, designed to generate steam at 250 pounds pressure. The outside dimensions of the new boiler are: Length, 7 feet; width, 66 inches; height, 42 inches. The grate area is 24 square feet, and the heating surface 600 square feet. The screw, also constructed by Mr. Mosher, is made of manganese-bronze; mean pitch, 66 inches; diameter, 3 feet; and has three blades.



BOILER ROOM OF THE "VAMOOSE."

The machinery of the *Now Then* is at present undergoing some alterations under the supervision of Mr. Mosher. Her best run on a measured mile with

original machinery and boilers was at the rate of 23 miles per hour, but when remodeled it is expected that the speed will be considerably increased.

The *Yankee Doodle* began her aquatic life on the Merrimac river at Amesbury, Mass., where she was known as the *Buzz*, being owned by her builder, and finally sold to Mr. Edward Hatch, of Newark, N. J., from whom she was purchased some three years ago by her present owners, the McBride brothers, of Philadelphia.

The principal dimensions of the *Yankee Doodle* are as follows: Length, 50 feet over all; beam, 6 feet 6 inches; 4 feet 10 inches at water line; depth, 3 feet; draught, 9 inches forward and 16 inches aft; the midship section is circular, and there is no outside keel; area of immersed midship section is 4½ square feet.

As originally constructed, steam was furnished by a locomotive boiler, which was recently replaced with a water-tube boiler having 360 feet of tubular heating surface, and a grate surface of about 8 square feet. The steam pressure carried is 150 pounds. It is claimed that the boiler shows steam in 2 minutes, while in 12 minutes the full pressure can be obtained. The coal bunkers will hold a ton and a half.

The engines are double cylinder, vertical, direct connected, 8 inches in diameter, with a stroke of the same length. They have steel bar frame and slipper guides. The cylinders are cast together, with bottom heads and steam chest in the middle. The valves are of the piston type, 3 inches in diameter, with maximum stroke of 2¾ inches and 2-inch stroke at one-quarter cut-off. The port opening is 7 square inches in area. The ports are straight, with but seven-sixteenths inch thickness between valve and cylinder bore. The clearance is 4 per cent. The entire valve gear, including eccentrics and links, is of steel. The links are a modified Porter-Allen type. The crank shaft is steel, with three main bearings, each 2⅝ inches in diameter by 6 inches long. The crank pins are hollow, 2⅝ inches in diameter, 4½ inches long. The piston-rod is 1¼ inches in diameter, and is of steel, as is also the piston. The connecting rods are forked, and are bored out in the center to lighten them. Ample provision is made for oiling all

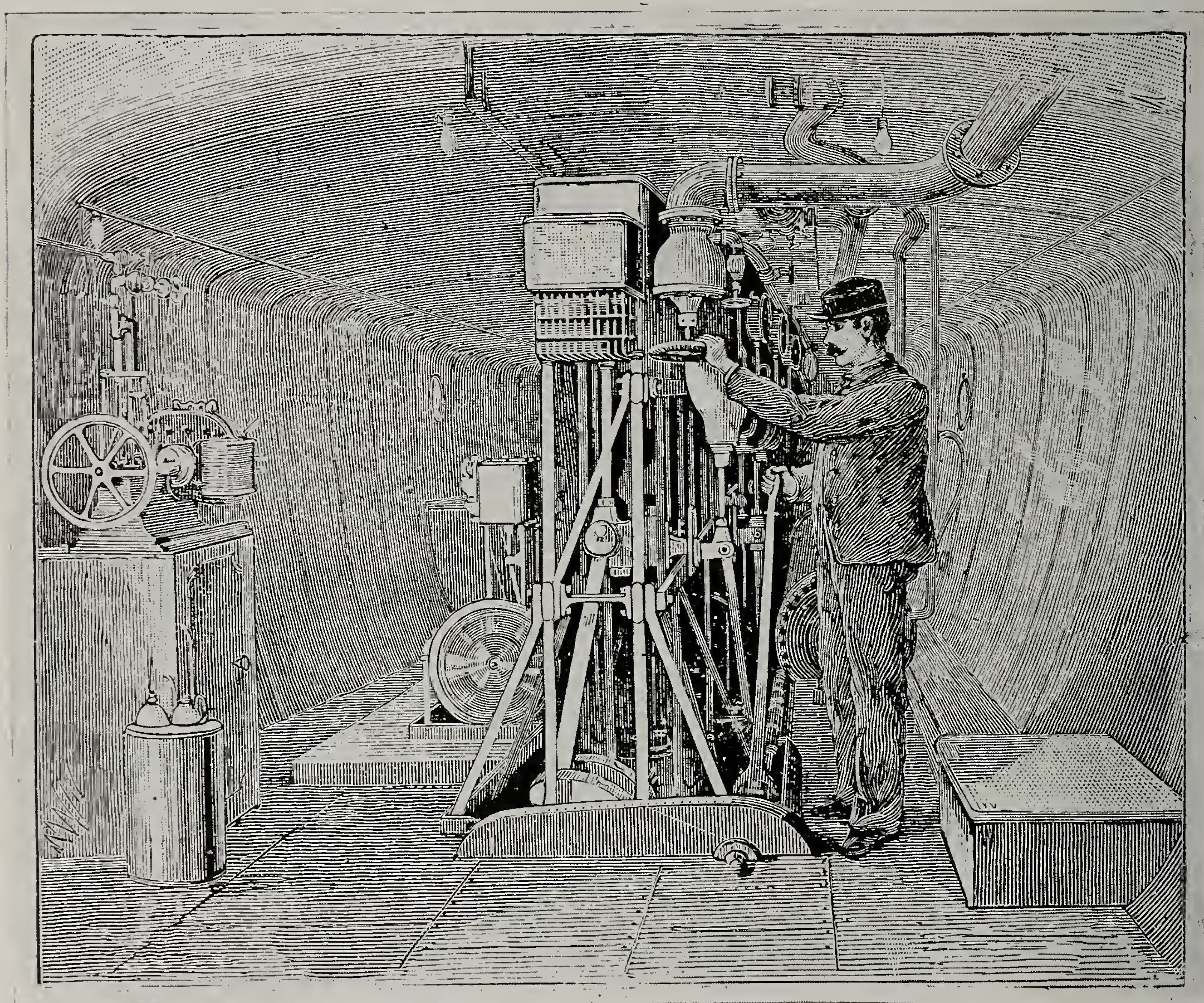
STEAM YACHT "VAMOOSE."

parts of the engines while running, besides the regular oil cups. The weight of the entire reciprocating parts of each engine is 33 pounds, or less than three-quarters of a pound per square inch of piston. This extremely light weight allows a speed of over 600 revolutions per minute without pounding or heating. The total weight of the engines complete is but 703 pounds. The screw shaft is steel, 2½ inches in diameter, with a ball thrust bearing. The screw, which is patented by Mr. Mosher, is of phosphor-bronze, with two blades finished all over, and is 34 inches in diameter, with 5 feet pitch.

The weight of the entire power plant is less than 4700 pounds. It has indicated over 160 horse-power, or about 29 pounds per indicated horse-power. The hull of the boat is constructed with oak frames and cedar planking. The frames are 1 inch by 1½ inches, spaced 8 inches between centers, mortised into an oak keel, and have a total displacement of about 4 tons.

The *Yankee Doodle*, seen in the illustration, on the Schuylkill river, Philadelphia, on July 4 of this year, made a remarkable run of a mile in 2.01$\frac{3}{5}$, assisted slightly by the tide.

The *Norwood* was also built by C. D. Mosher for N. L. Munro, of New York, after he had sold the *Now Then*, with the expectation of obtaining a faster yacht. She is only 63 feet 2 inches long over all, and about 60 feet long on the water line. She is 7 feet 2 inches



FROM THE "SCIENTIFIC AMERICAN."

ENGINES OF THE "VAMOOSE."

beam amidships, and her greatest draught is 22 inches, the draught forward being only about 9 inches. In designing the hull of the *Norwood*, and also of the *Yankee Doodle*, Mr. Mosher took as a foundation the general character of the hulls of successful torpedo boats. He made very extensive model experiments, and checked the results by dynamometric measurements on a number of models, each varying as the results of the measurements suggested, and the results were the models of the

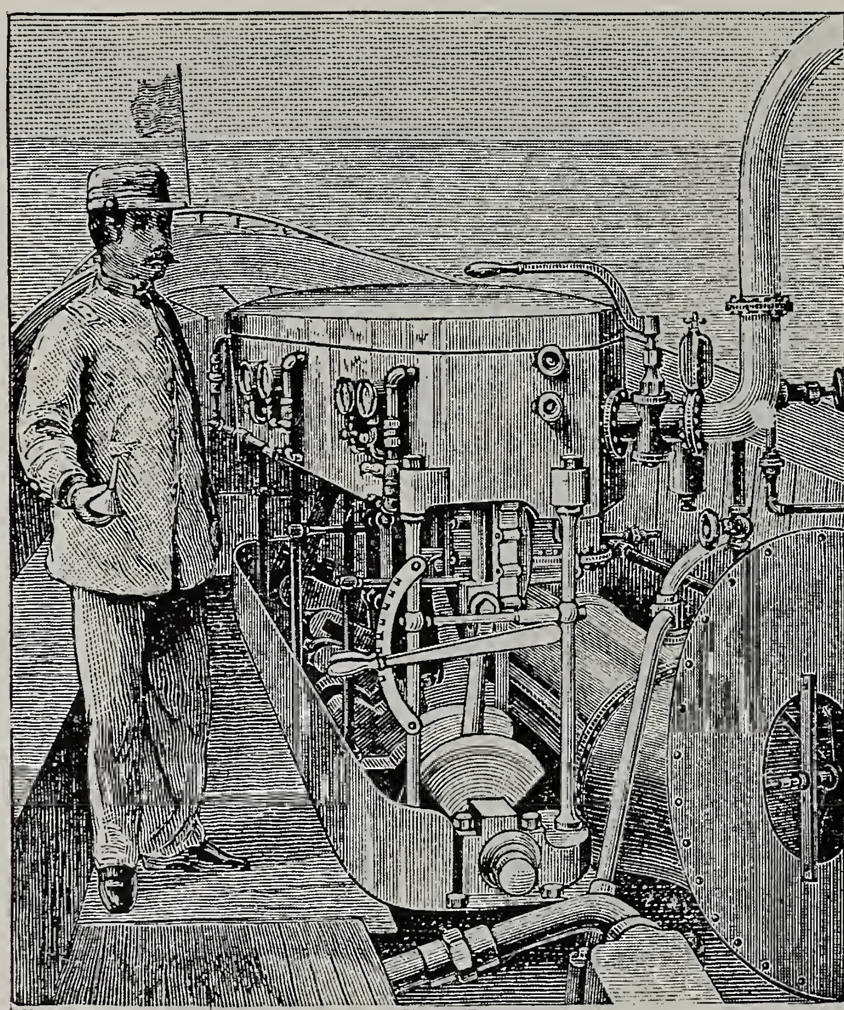
STEAM YACHT "YANKEE DOODLE."

Norwood and *Yankee Doodle*. Since it has been shown that the corresponding speed of the model and the full-sized boat varies as the square root of their respective lengths, the utmost reliance may be placed on such experiments, as evinced by the results as regards speed of the *Norwood* and *Yankee Doodle*; but in these experiments it requires the utmost care and delicacy in all the instruments, as well as great accuracy in the truthfulness of the displacements and model to that of the full-sized boat.

The hull of the *Norwood* is built of two thicknesses of mahogany on a strong oak frame, and has a steel keelson. The stern is cut away to make room for the propeller, which has three blades, and is 36 inches in diameter. It has a pitch of 7 feet, and is designed to be driven at the rate of 500 turns a minute. The engine is of the triple-expansion type, the cylinders being 9 inches, 14½ inches, and 22 inches in diameter respectively, and the stroke is 9 inches. At 500 revolutions a minute the engine will develop 450 horse-power. The valves are of the piston type, and operated by a single eccentric-link motion of the Porter-Allen type. In a vessel of this class every detail which can be eliminated is of the greatest importance, and the adoption of this valve gear renders it feasible to reduce weight materially, and at the same time maintaining full control and economical distribution of the steam. Weight has been taken out wherever possible; the shafts are hollow, and the connecting rods are bored

out the entire length, not only reducing weight, but serving as well to carry a solid lubricating material in the shape of a grease candle, which acts at once in case the oil lubrication stops from any cause.

The boiler, which is patented by Mr. Mosher, is of the water-tube type, and, as will be seen by reference to the illustration, is peculiar in appearance and construction. The center of gravity is very low, the total height being only 42 inches over everything, and the grate surface very large, extending practically the whole length and width of the boiler. There are two steam drums, one upon each side, the water drums being also at each side and one in the center. From the water drums the water tubes curve inwards and upwards, entering the steam drums as shown. These are wholly removed from the direct action of the fire, as are all the joints, not one, either steam or water, being exposed. The fire passes twice the length of the boiler, and the action of the fire, both going and returning, is always taken upon a solid surface of metal inclosing only water. No heat ever strikes a steam surface directly. This absence of joints and fittings in or out of the fire not only removes a cause of anxiety as to their durability, but it enables the builder to dispense with extra weight. This boiler weighs only 4000 pounds, and is amply 400 horse-power, being only 10 pounds dead weight per horse-power. The total heating surface is nearly 1000 feet, and is all contained in a space of 42 inches by 87 inches long and 72 inches wide. The working pressure is 200 pounds per square inch. The condenser is 5 feet long and 18 inches in diameter. The independent air and steam pumps are of the duplex type, very light, strong, and compact, and are run at a very high speed. There are two feed pumps, the steam cyl-

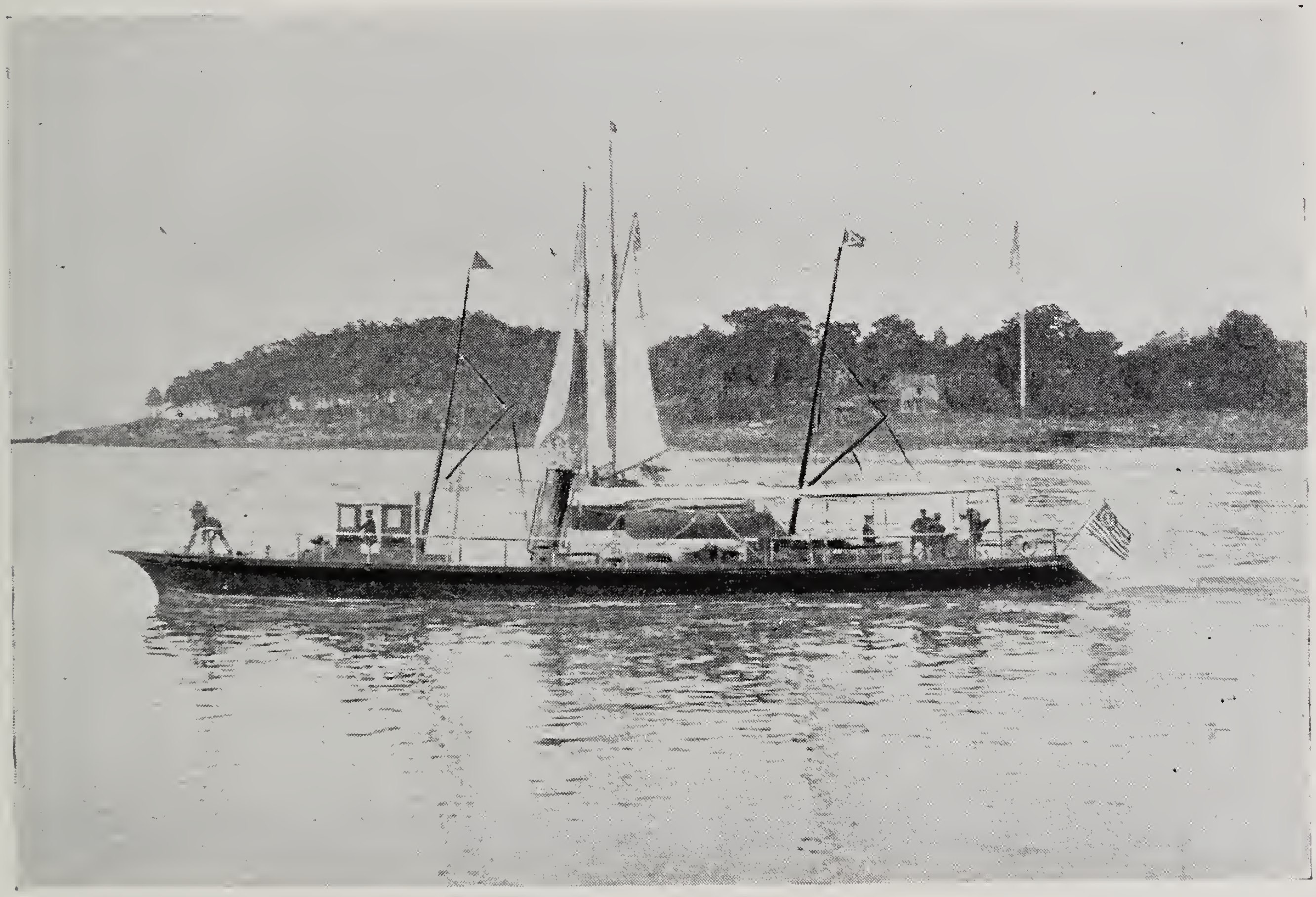


ENGINES OF THE "NORWOOD."

inders of which are $3\frac{1}{4}$ inches and the water cylinders $1\frac{1}{4}$ inches in diameter, and the stroke is 4 inches; the air pump is 4 by 6 by 5 inches. The smokestack rises 3 feet 9 inches above the top of the boiler, and is 18 inches in diameter. In cruising trim the boat is covered with an awning, which may be inclosed with glass, but in racing order she is stripped to the hull. The *Norwood* made her best record on the Merrimac while undergoing her preliminary trials. She then maintained a speed of 30 miles per hour for two hours, and made her fastest mile in 1 minute and 58 seconds.

The *Vamoose* was built by the Herreshoffs for W. R. Hearst, of San Francisco, at a cost of about $65,000. The length of the yacht is 112 feet 6 inches over all, and about 108 feet long on the water line, the extreme beam being 12 feet 4 inches and the greatest draught 4 feet 11 inches. The hull consists of a steel frame, uncovered in the interior of the boat, and with an outer covering of two layers of pine, the inside of which is seven-eighths inch thick white pine and the other five-eighths inch thick yellow pine. No money has been spent in the way of fancy finish or decoration.

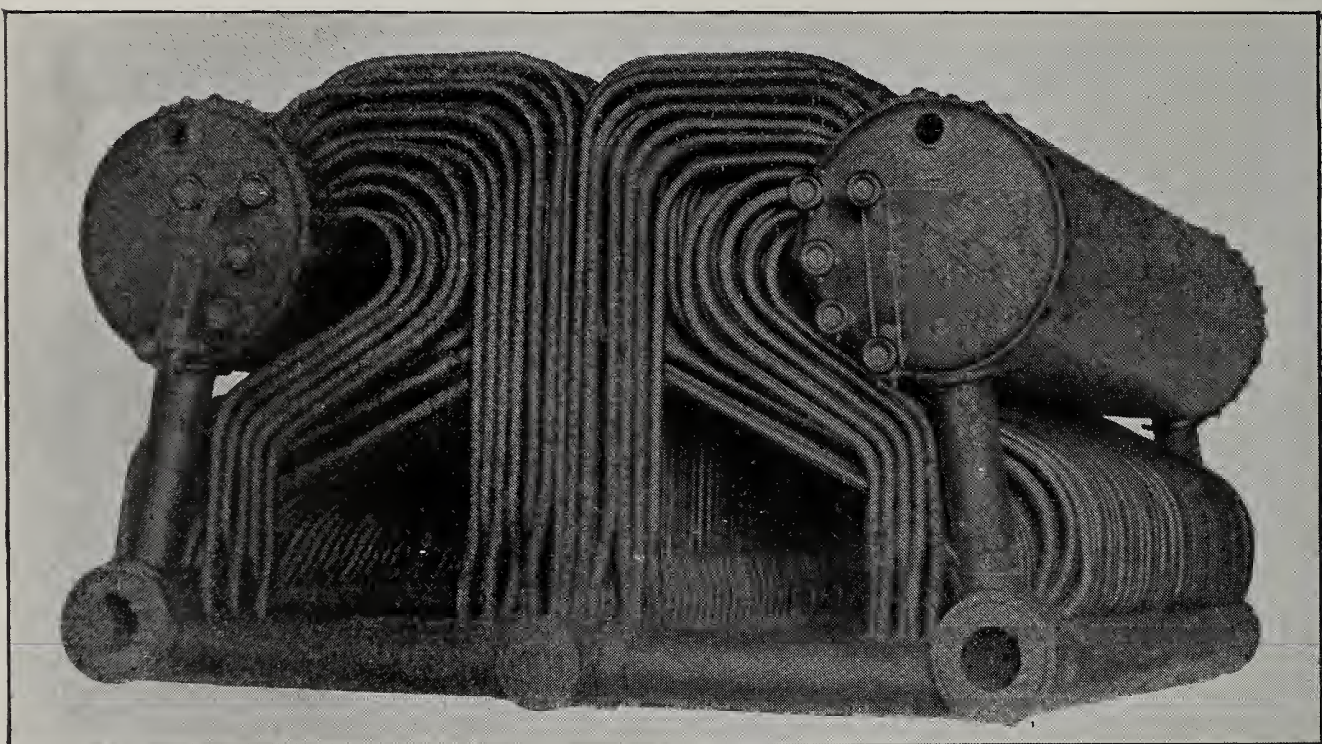
The *Vamoose* has quadruple-expansion engines, and there are five cylinders of the following diameters: One of $11\frac{1}{4}$ inches, one of 16 inches, and three of $22\frac{1}{2}$ inches each; the common stroke is 15 inches. The condenser is of copper, 5 feet 3 inches long and 31 inches in diameter, containing 498 square feet of cooling surface. The circulating pump is worked by an independent engine. The engine and its equipment weighs $13\frac{1}{2}$ tons, and is designed to develop 800 horse-power. The propeller shaft is $5\frac{1}{4}$ inches in diameter. The boiler is of the Thornycroft pattern, and is 8 feet 4 inches long and 8 feet 6 inches in diameter. It has three main drums and 8500 feet of cold-drawn steel tubing. Forced draught is afforded by a fan running up to 1000 revolutions



STEAM YACHT "NOW THEN."

per minute. The smokestack is 8 feet high above the deck, and is 36 by 21 inches in diameter. The boat is lighted by a Riker dynamo. The three-bladed Seise propeller of the *Vamoose* is 54 inches in diameter, and drops 21 inches below the lowest part of the keel. It is designed to be run at 400 revolutions per minute in order to propel the boat at full speed.

These four vessels represent the best and latest practice in the construction of high-speed steam yachts. The early steam yachts were designed by builders whose technical knowledge consisted of an acquaintance with certain trade terms and shop traditions, together with some knowledge of steam engineering. How imperfect their empirical methods were has been shown by the really wonderful increase that has been made in the speed and stability of yachts since scientific methods have had some hand in their designing. The greatest progress has been made during the last few years in the application of scientific principles to the designing of steam yachts, largely in consequence of the intense competition in the production of swift and costly vessels. The efficiency of the screw has been increased by its more perfect adaptation to the form of the hull; the power of the multiple-cylinder engine has rapidly advanced as the capacity of the steam generators increased; the machinery has been lightened by proportioning the size of the parts to the stresses that were to come upon them; and in many other ways the profession of naval architecture has come to approach that of an exact science. It is indeed difficult to see to-day in what direction there is much room for improvement in building fast steam craft.



NEW BOILER DESIGNED FOR THE "NORWOOD" BY C. D. MOSHER.

NOTES ON THE BLAST FURNACE.*

By John Hartman.

THE Phœnicians taught the Greeks the manufacture and use of iron, history tells us, about 1500 to 1600 years before Christ. After that time Greek history gives some detailed account of it. The Phœnicians, before leaving their original home on the Indian Ocean, practiced the art of iron-making, and on migrating to the Land of Canaan, whose hills were well covered with wood and contained iron ore, they made iron and sold it to the neighboring nations.

Tracing its early history back, it is lost in the twilight of fable. The hurling of Hephæstus from Olympia and the working of iron established by that act, when divested of its fiction, will be found to be the falling of an iron meteorite and the use made of it.

The Cretans' claim to the discovery of iron-making is more rational. Mount Ida in Crete was well wooded, and had a fine vein of iron ore on its side. Timber left to grow, decay, and fall will accumulate to quite a depth. This timber being accidentally fired at the bottom of the mountain by the inhabitants, in burning upwards burns slower, as the smoke and carbonic acid from below prevents the air from getting freely at the fire above to support combustion. This slow combustion favors turning the wood into charcoal, which, covering any pieces of iron ore, they are reduced or deoxidized by contact with solid carbon. As the wood below is burned off, the pure air, sweeping up the hot mountain side, is heated by the ground and rocks, and the charcoal over the ore is burned off at a high heat, causing the slag to flow from the reduced iron, leaving the iron remain as a sponge, which is easily hammered into wrought iron. We have here in nature's work the hot blast and the principle of regenerative furnaces.

The Phœnicians, however, being the older nation, must have the honor of first discovery, and to them more than any other nation the world is indebted for metallurgical science and massive structures. How these people could transport and erect the blocks of stone forming their structures is a puzzle to modern engineers, who with their best appliances can only lift one-fourth of their weight. They used steel tools, as is shown by the grooves in their quarries, and grappling irons were used to handle the blocks, to which the holes in them attest. All ancient iron was made by reducing pure oxides in a shallow charcoal fire, forming a sponge, and then hammering out the slag, a process carried on to this day.

The oldest and finest of all ruins are at Baalbec, Syria. Their columns, seven feet diameter, in three sections of twenty-four feet each, were held together by wrought-iron dowels, but these have been dug out by the Turks and Arabs during the dark ages to get material for implements of war and agriculture. They replaced a people of superior intelligence by their rugged nature and strength of muscle, but could not make a pound of iron. In all the Egyptian ruins the same destruction is noted. The massive coping stones of the temples were held together with iron clamps, but they have all been dug out, and much of the work of these grand old masters has been destroyed by the lazy, arrogant vandals of the dark ages.

To make steel, the ancients submitted wrought iron to the cementation process, which is heating the iron in a closed vessel in contact with carbon at a red heat. In this state it absorbs suf-

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ficient carbon to harden it and give it steely qualities. This process is carried on in India to-day.

Aristotle gives us a few notes on iron, but Pliny speaks more freely, thus: "Nature, in conformity with her usual benevolence, has limited the power of iron by inflicting upon it the punishment of rust, and thus displays her usual foresight in rendering nothing in existence more perishable than the substance which brings the greatest danger upon perishable mortality."

He states that the method of making iron is the same as that employed in making copper, and while some ores produce a metal that is soft and nearly akin to lead, others produce a brittle, coppery iron. Also that "it is a remarkable fact that when the ore is fused the metal becomes liquefied like water, and afterwards acquires a spongy, brittle texture." This can be seen to-day in any Catalan forge, where the slag accumulates, and on tapping off runs like water, leaving behind a brittle, spongy mass, which, being consolidated by the hammer, becomes soft and tough. The brittleness is overcome by patting the bloom at first with light blows until it is compacted, then striking heavy blows, and drawing it into billets. Also that "iron which has been burned in the fire is spoiled, and is useless until it is forged with the hammer"; this refers to the burned part being worked off in scale and sparks, and that "some iron cannot be worked at a red heat, but must be a bright yellow." This is the modern red-short iron. The iron, he says, "that is used for hob-nails is soft like lead," which corresponds to our pure neutral iron, made in the Catalan forge.

The earliest records of furnaces for making molten iron (not sponge) show a hole some fifteen inches diameter and three feet high in a clay bank. This was filled with charcoal, and blown with air caught by deflectors and conveyed to the interior through pipes or reeds. After the furnace was warmed up with the burning coal, charges of ore and coal were put in, and after a few hours a lump of molten iron was taken out of the crucible by tearing the crucible open. This iron contained a little combined carbon, and if it had the right quantity it could be worked into steel at once, or it could be decarbonized and made into wrought iron. The slag formed in these furnaces was silicate of protoxide of iron, from the fusion of part of the ore with the gangue. It was tapped off from the furnace when it accumulated too high.

Carbon exists in iron as combined carbon or as graphitic carbon. Combined carbon makes iron steely or hard; graphitic carbon denotes soft iron. After bellows, made of pig or goat skins and operated by the foot or hand, were invented, higher heats could be obtained. This necessitated the use of more refractory material for the furnace, and caused separate structures to be built. The higher heats gave more combined carbon to the iron, which was worked off in another fire. After the Germans began making iron, they built their furnaces or stuckofens higher, to economize heat and save charcoal, as they found wood getting scarce. In these higher furnaces the ore and coal collected the ascending heat and returned it to the crucible, increasing its heat and giving them an iron of different character. Part of the carbon was chemically combined and part was mechanically mixed with the grains, giving the iron a dark color and fluidity so that it would run like molten lead. As this iron was difficult to decarbonize, they called it bad or sow iron.

Prior to the thirteenth century the art of iron-founding was unknown, but with the use of higher furnaces a metal was made that was fluid and could be cast, which soon came into use and formed a new branch of the iron business. As the old German furnaces were small, they ran the combined carbon iron out in a long groove made in the sand, as the iron was mushy and flowed with difficulty from the furnace. When they used higher furnaces, and made iron with graphitic carbon which ran fluid, they ran short grooves at right angles to the long groove, and, filling them with metal, they called them pigs, a practice in use to-day.

By some it is thought the head of the battering ram used by the ancients was cast iron, but it is too brittle for that purpose; it was forged to the shape shown on ancient monuments. Only

rich, pure ores could be used by the ancients. They could not get the intensity of heat in their furnaces to give them graphitic carbon in the iron; hence they could only make wrought iron.

Among the earliest appliances of cast iron in founding was to make cannon, but they frequently burst in the third or fourth round, and killed as many friends as enemies, like some of the canonical laws made at times in the world's progress.

After the iron business had been conducted in England for many years, the wood becoming scarce, they turned their attention to mineral fuel or coal, with more or less success. About 1630 Dud Dudley experimented with coke.

In 1735 Abraham Darbey, of England, made the first successful blast with coke, and from that day to this it has been continued in making pig iron.

In 1837 anthracite came into use for pig-iron making in Wales, and is continued in Pennsylvania to the present time.

In 1828 Neilson first applied heated air to the furnace, which raised the temperature of the crucible and allowed a more basic or limy flux to be used. This melts at a high temperature, but picks up the sulphur in the ore and fuel and gives a better iron. With the introduction of hot air, cheaper ores, but containing a higher percentage of sulphur and silica, could be used, which lowered the cost.

The heat of the crucible has been further increased by the use of regeneratives stoves giving lower fuel consumption, more output, and better iron, as the less fuel used the less impurity goes from the fuel to the iron.

While metals, as a rule, increase in value with their purity, pure iron has no commercial existence, and is never known outside of the chemical laboratory. Its value is only established when it is combined with carbon, but some of the following elements always accompany it in greater or less quantities, and modify its character: silicon, manganese, magnesium, sulphur, phosphorus, and aluminum. In chemical combination with iron there is no exact line of demarcation with these elements. Carbon exists in pig iron in the combined or the graphitic state, or in both states. Combined carbon closes the grain of iron, making it smaller and harder. Graphitic carbon is the combined carbon changed by high heat to the graphitic state, which softens the iron. Silicon destroys the grain of the iron, making it weaker, softer, and cold-short. Manganese destroys the grain, weakens it, and makes it red-short. Magnesium is claimed to soften and strengthen iron. Phosphorus is an unwelcome ingredient, which cannot be eliminated and has to be tolerated; it weakens iron and makes it cold-short. Sulphur is a vigilant enemy, closing the grain, making it harder, and causing red-shortness; but it can be eliminated. Aluminum strengthens and softens iron, Copper makes iron red-short. Cold-short iron will work in the smith's fire at a low heat, but is weak when cold. Red-short iron will work only at a high heat, but is strong when cold. If the iron is not worked at the heat to suit its nature it will crumble or break.

Pig iron is sold in the market in five grades, Nos. 1, 2, 3, 4, and 5. Besides these there are special grades, established recently but used extensively, namely: low phosphorous and sulphur iron, used in the open-hearth and Bessemer processes, and low silicon with high-phosphorous iron, used in the basic process. Silicized iron containing four per cent. to seven per cent. of silicon is also made to soften other irons and make them run liquid.

ANALYSIS OF A STANDARD NO. I PIG IRON.

	Per Cent.
Iron	92.37
Graphitic carbon	3.52
Combined carbon	.13
Silicon	2.44
Phosphorus	1.25
Sulphur	.02
Manganese	.28

Gray.—A large, dark, open-grain iron, softest of all the numbers, and used exclusively in the foundry. Tensile strength low. Elastic limit low. Fracture rough. Turns soft and tough.

NO. 2 PIG IRON.

	Per Cent.	
Iron	92.31	*Gray.*—A mixed large and small dark grain, harder than No. 1 iron, and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture less rough than No. 1. Turns harder, less tough and more brittle than No. 1.
Graphitic carbon	2.99	
Combined carbon	.37	
Silicon	2.52	
Phosphorus	1.08	
Sulphur	.02	
Manganese	.72	

NO. 3 PIG IRON.

	Per Cent.	
Iron	94.66	*Gray.*—Small, gray, close grain, harder than No. 2 iron, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns harder, less tough and more brittle than No. 2.
Graphitic carbon	2.50	
Combined carbon	1.52	
Silicon	.72	
Phosphorus	.26	
Sulphur	trace	
Manganese	.34	

NO. 4 PIG IRON.

	Per Cent. A.	Per Cent. B.	
Iron	94.48	94.08	*Mottled.*—White background, dotted closely with small black spots of graphitic carbon, little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3.
Graphitic carbon	2.02	2.02	
Combined carbon	1.98	1.43	
Silicon	.56	.92	
Phosphorus	.19	.04	
Sulphur	.08	.04	
Manganese	.67	2.02	

[The manganese in this (*B*) pig iron replaces part of the combined carbon, making the iron harder and closing the grain, notwithstanding the lower combined carbon.]

NO. 5 PIG IRON.

	Per Cent.	
Iron	94.68	*White.*—Smooth, white fracture, no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit much lower than No. 4. Too hard to turn and more brittle than No. 4.
Combined carbon	3.83	
Silicon	.41	
Phosphorus	.04	
Sulphur	.02	
Manganese	.98	

Fig. 1, of the plate, shows the fracture of a No. 1 pig of the Thomas Iron Company (as are all the others). The large patches show the grain of the iron, which is rough and projects up in sharp points. On examining it with a powerful glass the grains of iron are found embedded in the graphitic carbon, similar to a wall of rubble masonry laid solid in mortar. The grains are connected, but the interstices are filled with the graphite. Graphitic carbon high, combined carbon low.

Fig. 2, of the plate, shows the fracture of a No. 2 pig. The patches are smaller, showing a smaller grain. Graphitic carbon lower, and combined carbon higher than No. 1.

Fig. 3, of the plate, shows fracture of No. 3 pig. The patches are smaller than No. 2, and show smaller grain. Graphitic carbon lower, and combined carbon higher than No. 2.

Fig. 4, of the plate, shows fracture of No. 4 pig. The patches are smaller, and more of them than in No. 3, and show little or no grain. Graphitic carbon lower, and combined carbon higher than No. 3.

Fig. 5, of the plate, shows fracture of

Figs. 1, 2, 3, 4, 5, and 6 are not shown in this article.

No. 5 pig. The patches are small and closer, but no grain. No graphitic carbon; all combined carbon.

The strength for tension culminates in No. 3 pig iron, but falls off more rapidly from No. 3 to No. 5 than from No. 3 to No. 1.

	Per Cent. Combined Carbon.
Malleable iron contains	.25
Steely iron contains	.35
Steel contains	.50
Hard steel contains	1 to 1.50

Taking the sum of the graphitic and combined carbon in each quality of pig iron, they are practically the same. The softness of pig iron is dependent on the amount of graphitic carbon in it. Separating the iron in the No. 1 pig from the graphitic carbon, it is a nearly pure wrought iron embedded in the graphitic carbon, and it is the absence of combined carbon which gives it the softness and flexibility that make it desirable for machinery and other purposes.

The grains of iron are crude crystals. When the iron is nearly pure and allowed to cool very slowly, regular octahedral crystals of iron are formed. Fine crystals were found twelve years ago in the hearth of Crown Point Furnace. They used an ore low in phosphorus, sulphur, and manganese. These crystals are now in the Academy of Natural Sciences, Philadelphia.

No. 1 pig iron may be defined as being composed of grains of wrought iron connected together but embedded in graphite. No. 2 pig iron has more combined carbon, which converts the wrought iron into a soft steel harder to the tool working it. No. 3 pig iron has more combined carbon, and the iron portion is a crude steel harder to the tool working it. Nos. 4 and 5 are virtually crude, high, combined-carbon steels.

The numbers here given, 1, 2, 3, 4, 5, for qualities of pig iron are the old standard. Some founders grade in six divisions, and in some cases ten to eleven grades are required for a given iron. If the impurities in pig iron were uniform, which would be the case if there were only one kind of ore and fuel, the proper plan would be to buy iron by chemical analyses on a basis of graphitic and combined carbon, but the impurities so change the character that the eye is found to be the best guide so far in fixing the grade. In running the ends of the fingers over the fracture of a pig of iron, if the ends of the grain tear the fingers the iron is strong. The analysis (*B*) of No. 4 pig iron shows low in combined carbon, but the manganese hardens the iron and changes it from gray to mottled iron.

Fig. 6, of the plate, is a hot-blast No. 1 charcoal iron from Grand Rivers, Ky. The pigs bend before breaking. The ends of the grain are sharp and tear the fingers. The analysis is as follows:

	Per Cent.
Silicon	1.955
Sulphur	.029
Phosphorus	.488
Manganese	.213
Graphitic carbon	3.310
Combined carbon	.460
Iron	93.545

On breaking this iron, the pig, when it strikes the breaking blocks, emits a dull thud like lead. It is an iron of high tensile strength, and well adapted for making car wheels. There are times in furnace practice when the first iron at a cast runs sluggish and mushy, but the iron on cooling is found to be excellent No. 1. This iron is the first formed directly after casting, and, lying near the tapping hole, has slowly lowered its temperature and formed coarse-grained iron. On opening the tapping hole the more fluid iron in the hearth pushes this cooler iron out first, and it is then followed by the fluid iron.

The bending of pigs is not confined to charcoal iron. Coke and anthracite iron do the same when using good stock and running the furnace at the proper temperature.

Referring to the pig-iron furnace section, Fig. 7, the air blown through the tuyere is quickly converted to carbonic oxide gas, and the heat from it keeps the fuel in the bosh at a white heat. The bosh and hearth are always filled with fuel when the furnace is working well. If the heat in the bosh becomes too high from a light burden, the silicon in the fuel is reduced, part of it going to the pig iron, giving a weak, light iron.

When silicon is reduced, the cinder will not take it up. What escapes the iron is burned to silica in the stoves and boilers; hence the heavy white fumes at the chimney top. Silicized iron was unknown to the ancients for want of heat to produce it. With a good burden of ore the heat of the bosh can be kept at the temperature given. As the ore reduces in the upper part of the furnace a finely divided carbon penetrates the ore and combines with the iron; when the iron melts out of the ore it leaves it with the carbon in the combined state. As it trickles down through the glowing fuel it may form some graphitic carbon, but as a rule it reaches the crucible with combined carbon only. With a clean, hot hearth the carbon in the iron is gradually transformed to graphitic carbon. As the fluid iron running from the furnace cools, more or less of the carbon separates as graphitic carbon, which is squeezed into the interstices between the grains as they form. If this pig iron is run against a cold plate the graphitic carbon is changed to combined carbon, and the lower the silicon in the pig iron the harder and greater is the depth of the change. If the thickness of the running iron is too great to change the whole thickness of the pig iron, then part of the pig will be close and hard, while the other part is open and soft. As more burden of ore is applied to the furnace the heat of the bosh and crucible is decreased, and No. 2, 3, 4, or 5 is produced as the bosh and hearth get cooler.

In making No. 1 iron the founder must be careful to keep a large, clean, hot crucible, as the finishing touches to the iron for grade are made in it. In the crucible alone, and not above it, must the intensity of the heat be applied to the iron to form graphite.

After the founder has made good No. 1 pig, it is sent to market and bought for the cupola. The cupola is charged with fuel and iron, the No. 1 iron being placed in the lower part of the cupola on a good bed of fuel; above it is more fuel, and on this is laid the harder iron. Suppose it is to make a roll: then No. 3 would be used. Blast is applied to the cupola; it burns up one side more than the other, and the hard iron above melts, comes down and mixes with the good No. 1 meant for pulleys; the result is, both irons are spoiled, and the founder making the No. 1 gets soundly berated for making an iron that changes in remelting.

Again, suppose all No. 1 is charged, and the iron is melted at a lower temperature than that at which it was made: the carbon will partly change from graphitic to combined carbon, and make the iron harder. Again, suppose the fuel is high in sulphur: the iron, in the absence of the strong basic cinder of the blast furnace, will take it up, closing the grain and making the iron harder; or, if the cupola scaffolds on one side, the air rushing up through the contracted opening decarbonizes the shots of falling iron and makes it harder. Iron melted with an excess of fuel will take up the kish or graphite formed by the intense heat, and on pouring the casting the cooling effect of the pouring squeezes out the graphite, which floats to the top of the mold and makes spongy castings. It is important to melt with the proper heat and no excess. Certain sands also exert a bad mechanical influence on pig iron by forming an asbestiform material that floats to the top of the mold, making defective castings.

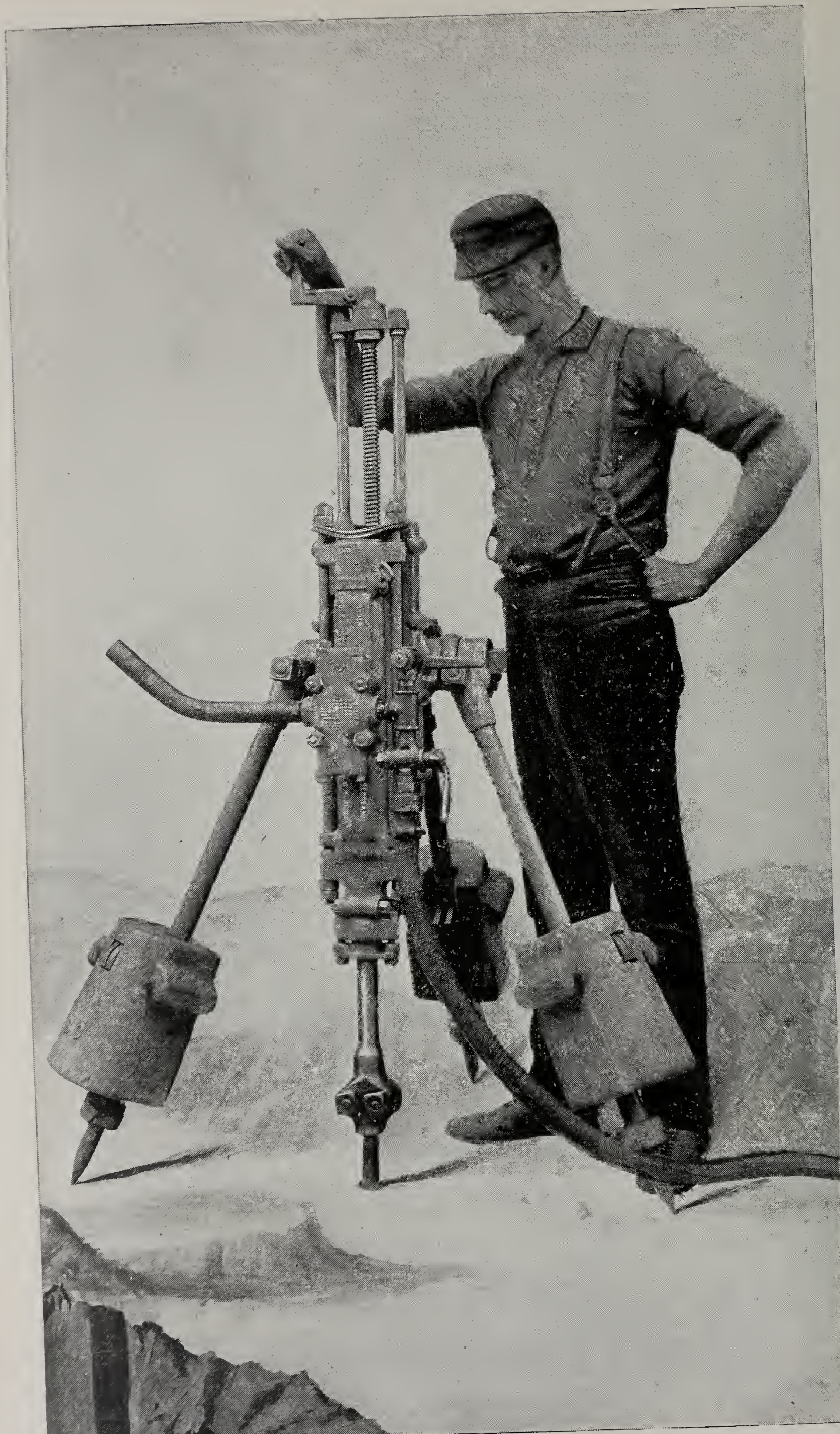
Iron, to retain its quality as sold, should be melted by gas containing no free air. The gas should be burned to carbonic acid with an excess of air while heating up the iron. As soon as melting begins, the gas should be burned to carbonic acid with a slight amount of carbonic oxide in excess, to take care of any truant air entering the furnace door. This can be accomplished by a regenerative furnace, using gas for heating. This furnace is the same as the open-hearth furnaces now in use in all our large steel works, and consists of a square building of iron plates, lined with refractory brick and having a basin-shaped hearth on bottom. At each end of the square building are two round iron stoves, filled with fire-brick having numerous passages from top to bottom of the bricks, called regenerators. The hearth and regenerators having been warmed up by wood, gas is turned through one of the regenerators, and air through the other along-

side of it. The gas and air meet at the end of the hearth and burn across it, heating it up and melting the iron placed on the bottom of the hearth. After the burned gas passes the hearth it enters the two opposite regenerators, heating them up. When the two first regenerators begin to cool off the valves are reversed, and the gas and air sent back over the iron and through the other two regenerators. The burned gas in passing through the two first regenerators heats them up, when another reverse is made, and so on until night. By this arrangement all the waste heat of the furnace is utilized except the heat escaping in the carbonic acid at the chimney, which is about 350°. Comparing this with the 2000° escaping at the chimney of the cupola, a saving is effected in fuel. It will be safe to take the saving at 100 pounds fuel per ton of iron melted, which will pay the interest on difference of cost between the cupola and open-hearth regenerative plant.

With this furnace, slow or quick melting and hot or cold melting can be had at once ; no sulphur will be taken up by the iron, and it can be kept at any desired heat, which avoids a change in the original quality. A perfect mixture can be made, as different irons charged when melted can be well stirred through the doors and made homogeneous. No precision of this kind can be obtained with the cupola, as it is guess-work when certain qualities of iron get down to the melting point, and they cannot be stirred except in the ladle, which may not get equal quantities of each iron. No graphite can be formed in this furnace to make poor castings. An objection to this furnace will be the loss of heat keeping it hot over night with a small volume of gas, but it has the advantage of being ready in the morning for work as soon as the men arrive. As the high heat used in open-hearth steel plants is not required for melting pig iron, the loss in heat to keep furnace warm over night would be slight. With the improved cranes and appliances for handling the metal, there is no longer need of suspending all molding while pouring. When this system is taken up and worked out carefully in all its details, it will prove a decided success, as molding and pouring can go on side by side.

From the data now being collected by the different iron works, some active brain in the future will give the world a table showing how each element affects the pig iron, and by it a founder will be enabled to make his mixture to produce the required results without having recourse to trial for each brand of pig iron.

The blast furnace is still in its infancy, yet in this country it has made rapid strides, and gone far beyond Europe in output and low fuel consumption.



A MODERN DRILL.

MODERN METHODS OF QUARRYING.*

By William L. Saunders, Mem. Am. Soc. C.E.

THERE are doubtless many persons, some of them perhaps not without a knowledge of quarrying, who have read extracts from the census reports, and have noted frequent reference to a system of blasting known as the Knox system. This system is a recent invention. No mention was made of it in the tenth census, and no description has yet been given of it in any publications on quarrying. The first work done by this method was in 1885, and at the close of that year two quarries had adopted it. In 1886 it was used in 20 quarries; in 1887, in 44; in 1888, in upward of 100, and at the present time about 300 quarries have adopted it. Its purpose is to release dimension stone from its place in the bed by so directing an explosive force that it is made to cleave the rock in a prescribed line and without injury. The system is also used for breaking up detached blocks of stone into smaller sizes.

Quarrymen have, ever since the introduction of blasting, tried to direct the blast so as to save stock. Holes drilled by hand are seldom round. The

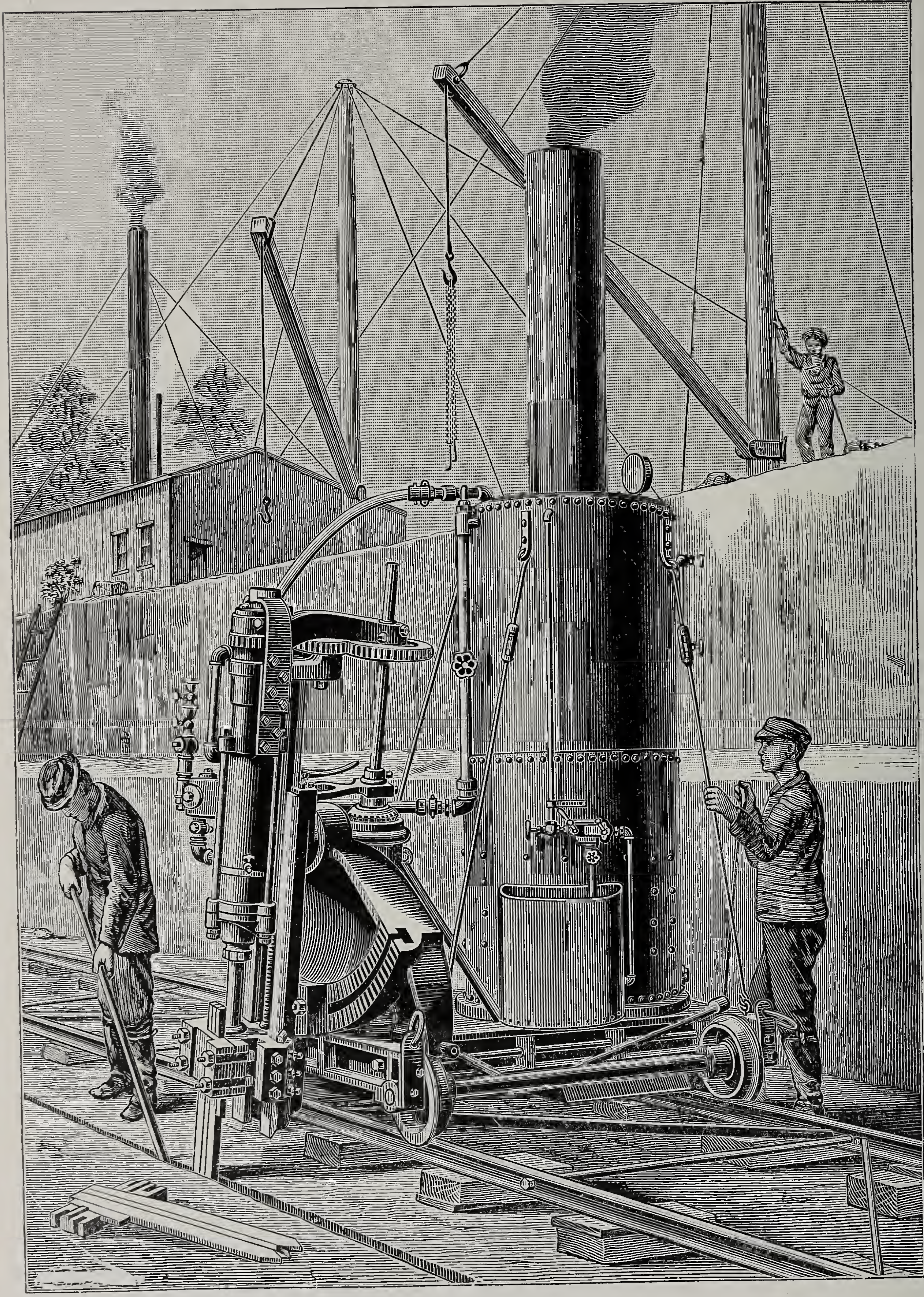
FIG. 1.

shape of the bit and the irregular rotation while drilling usually produce a hole with a triangular section, the walls of the hole taking the shape shown in Fig. 1. It was observed many years ago that, when a blast was fired in a hand-drilled hole, the rock usually broke in three directions radiating from the points of the triangle in the hole. This led quarrymen to look for a means by which the hole might be shaped in accordance with a prescribed direction of cleavage.

The oldest sandstone quarries in America are those at Portland, Conn. It was from these quarries that great quantities of brownstone were shipped for buildings in New York. The typical "brownstone front" is all built of Portland stone. As the Portland stone quarries were carried to great depths the thickness of bed increased, as it usually does in quarries. With beds from 10 to 20 feet deep, all of solid and valuable brownstone, it became a matter of importance that some device should be applied which would shear the stone from its bed without loss of stock and without the necessity of making artificial beds at short distances. A system was adopted and used successfully for a number of years, which comprised the drilling of deep holes from 10 to 12 inches in diameter, and charging them with explosives placed in a canister of peculiar shape. The drilling of this hole is so interesting as to warrant a passing notice. The system was similar to that followed with the old-fashioned drop drill. The weight of the bit was the force which struck the blow, and this bit was simply raised or lowered by a crank turned by two men at the wheel. The bit resembled a broadaxe in shape, in that it was extremely broad, tapering to a sharp point and convex along the edge.

Fig. 2 illustrates in section one of the Portland drills, and a drill hole with the canister containing the explosive in place. This canister was lune-shaped, —that is, its section was bounded by two minor segments of a circle. The canister was made of two curved pieces

*Paper read before American Society of Civil Engineers.



COMPLETE STONE-CHANNELING MACHINE.

of sheet tin with soldered edges, cloth or paper being used at the ends. It was surrounded with sand or earth, so that the effect of the blast was practically the same as though the hole were

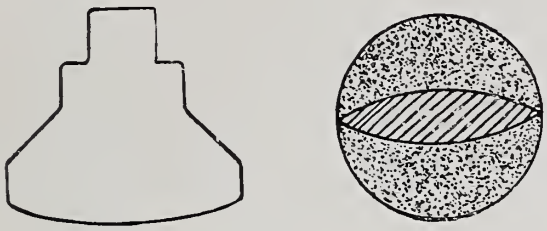


FIG. 2.

drilled in the shape of the canister. In other words, the old Portland system was to drill a large, round hole, put in a canister, and then fill up a good part of the hole. Were it possible to drill the hole in the shape of the canister, it would obviously save a good deal of work which had to be undone. The Portland system was, therefore, an extravagant one, but the results accomplished were such as to fully warrant its use. Straight and true breaks were made, following the line of the longer axis of the canister section. See Fig. 3.

It was found that, with the old Portland canister, two breaks might be made at right angles by a single blast, when using a canister shaped like a square prism. In some of the larger blasts, where blocks weighing in the neighborhood of 2000 tons were sheared on the bed, two holes as deep as 20 feet were drilled close together, the core between the holes was then chipped out, and

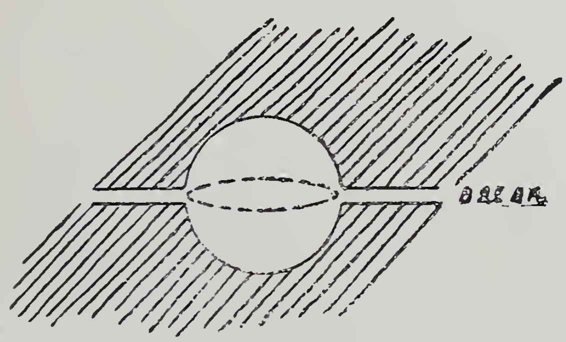


FIG. 3.

large canisters measuring two feet across from edge to edge were used.

Another of the older systems of blasting is that known as Lewising (Fig. 4). A Lewis hole is made by drilling two or three holes close together and parallel with each other, the partitions between the holes being broken down by using what is known as a broach. Thus a wide hole or groove is formed, in which powder is inserted, either by ramming it directly in the hole or by putting it in a canister shaped somewhat like the Lewis-hole trench. A complex Lewis hole is the combination of three drill holes, while a compound Lewis hole contains four holes. Lewising is confined almost entirely to granite. In some cases a series of Lewis holes is put in along the bench, at distances of 10 and 25 feet apart, or even greater, each Lewis hole being situated equidistant from the face of the bench. The holes are blasted simultaneously by the electric battery.

Another system used to a limited extent, and by no means to be commended, is one involving the use of

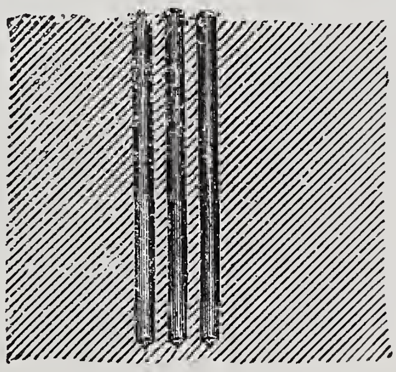


FIG. 4.

inverted plugs and feathers. The hole, which in this case is an ordinary one, is first charged with powder; then the plugs and feathers are inserted as a sort of tamping, the effect of the blast being to drive the plugs between the feathers and to split the rock by the usual plug and feather process. This is rather a violent way of using this process, and it frequently results in irregular breaks and in damage to the rock at the top of the hole.

It is thus seen that the "state of the art" has been progressive, though it was imperfect. Mr. Sperr, in his reference to this subject made in the report of the tenth census, says: "The influence of the shape of the drill hole upon the effects of the blast does not seem to be generally known, and a great

A SANDSTONE QUARRY IN OHIO.

waste of material necessarily follows." This was written but a few years before the introduction of the new system, and it is doubtless true that attention was thus widely directed to the conspicuous waste due to a lack of knowledge of the influence of the shape of a drill hole on the effect of a blast. The system developed by Mr. Knox practically does all and more than was done by the old Portland system, and it does it at far less expense. It can best be described by illustrations.

Fig. 5 is a round hole, drilled either by hand or otherwise,—preferably otherwise, because an important point is to get it round. Fig. 6 is the improved form of hole, and this is made by inserting a reamer, Fig. 7, into the hole in the line of the proposed fracture,

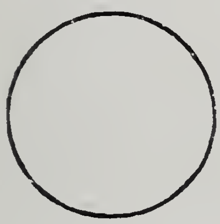


FIG. 5.

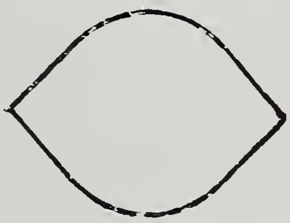


FIG. 6.

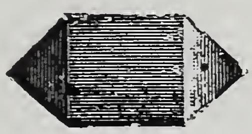


FIG. 7.

thus cutting two V-shaped grooves into the walls of the hole. The reamers are further shown in Fig. 8. The blacksmith tools for dressing the reamers are shown in Fig. 9. The usual method of charging and tamping a hole in using the new system is shown in Fig. 10. The charge of powder is shown at *C*, the air space at *B*, and the tamping at *A*. Fig. 11 is a special hole for use in thin beds of rock. The charge of powder is shown at *D*, the rod to sustain tamping at *B*, air space at *CC*, and tamping at *A*.

Let us assume that we have a bluestone quarry in which we may illustrate the simplest application of the new system. The sheet of stone which we wish to shear from place has a bed running horizontally at a depth of say 10 feet. One face is in front, and a natural seam divides the bed at each end at the walls of the quarry. We now have a block of stone say 50 feet long, with all its

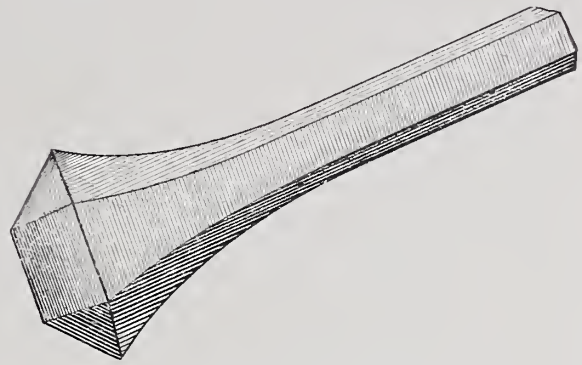


FIG. 8.

faces free, except one,—that opposite and corresponding with the bench. One or more of the specially formed holes are put in of such depth and distance apart, and from the bench, as may be regulated by the thickness, strength, and character of the rock. No man is so good a judge of this as the quarry foreman who has used and studied the effect of this system in his quarry. Great care should be taken to drill the holes round and in a straight line. In sandstone of medium hardness these holes may be situated 10, 12, or 15 feet apart. If the bed is a tight one, that is where it is not entirely free at the bottom, the hole should be run entirely through the sheet and to the bed; but with an open, free bed, holes of less depth will suffice.

The reamer should now be used and driven by hand. Several devices have been applied to rock drills for reaming the hole by machinery while drilling,—that is, efforts have been made to combine the drill and the reamer. Such efforts have met with only partial success.

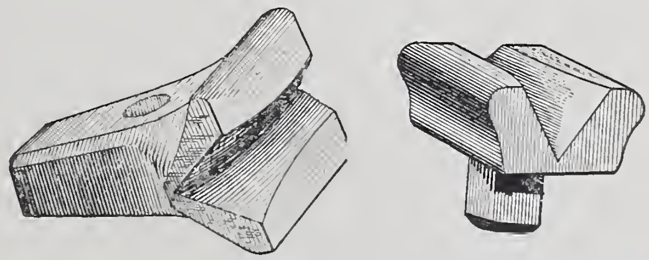
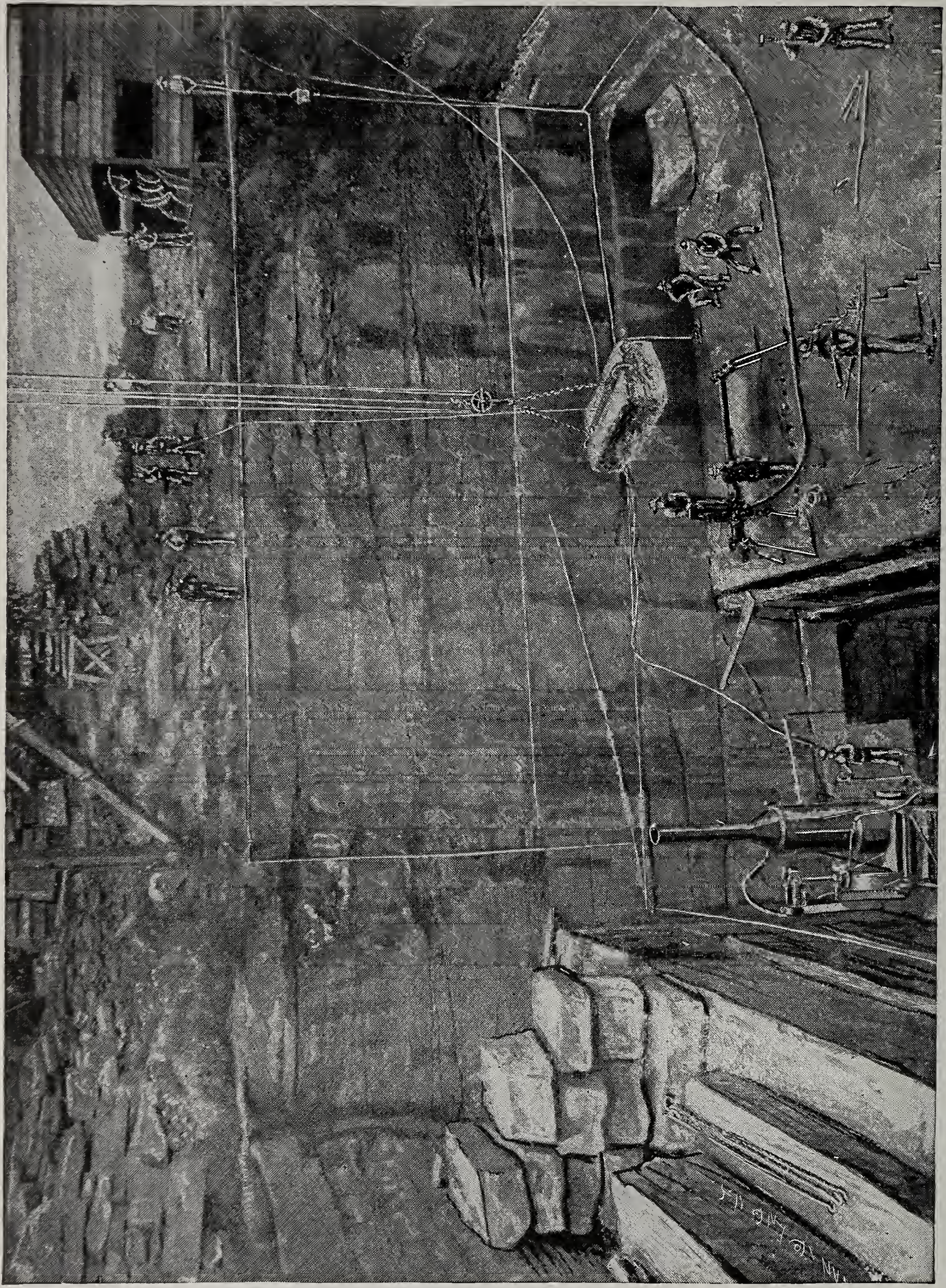


FIG. 9.

The perfect alignment of the reamer is so important that where power is used this point is apt to be neglected. It is also a well-known fact that the process of



A QUARRY IN GEORGIA.

reaming by hand is not a difficult or a slow one. The drilling of the hole requires the greatest amount of work.

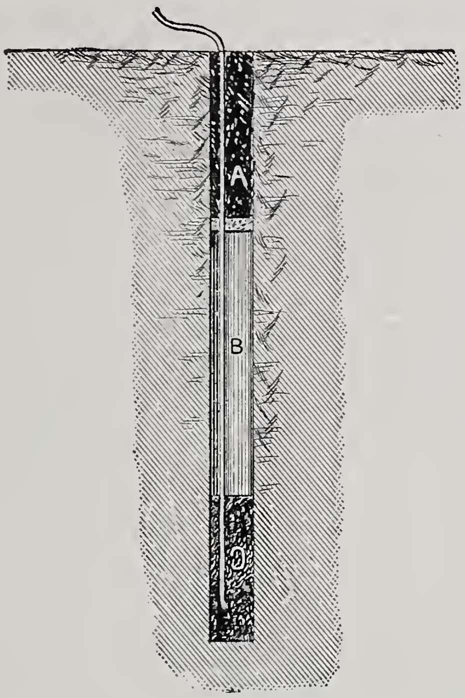


FIG. 10.

After this has been done it is a simple matter to cut the V-shaped grooves. The reamer should be applied at the center of the hole,—that is, the grooves should be cut on the axis or full diameter of the hole. The gage of the reamer should be at least $1\frac{1}{2}$ times the diameter of the hole. While driving the reamer great care should be taken that it does not twist, as the break may thereby be deflected, and the reaming must be done also to the full depth of the hole.

The hole is now ready for charging. The powder should be a low grade of explosive. Dynamite is not suitable, and Black powder, Judson powder, or other explosives which act slowly are preferable. No definite rule can be laid down as to the amount of powder to be used, but it is well to bear in mind that it should be as small as possible. As a matter of fact, very little powder is required in most rocks. Hard and fine-grained stone requires less powder than soft stone. This is based on the same principle of philosophy that granite will split by the plug and feather process with holes of less diameter and depth and with less expenditure of force than sandstone. Mr. Knox tells of a case which came under his observation, where a block of granite "more than 400 tons weight, split clear in two with 13 ounces of FF powder." He compares this with a block of sandstone of less than 100 tons weight "barely started with $2\frac{1}{2}$ pounds of the same grade of powder, and requiring a second shot to remove it."

It is obvious that enough powder must be inserted in the hole to produce a force sufficient to move the entire mass of rock on its bed. In some kinds of stone, notably sandstone, the material is so soft that it will break when acted upon by the force necessary to shear the block. In cases of this kind a number of holes should be drilled and fired simultaneously by the electric battery. In such work it is usual to put in the holes only four or five feet apart. The powder must, of course, be provided with a fuse, or preferably a fulminating cap. It is well to insert the cap at or near the bottom of the cartridge, as shown in Figs. 10 and 11.

After the charge, the usual thing to do is to insert tamping; but in the improved form of hole the tamping should not be put directly upon the powder, but an air space should be left as shown at *B*, Fig. 10. The best way to tamp, leaving an air space, is first to insert a

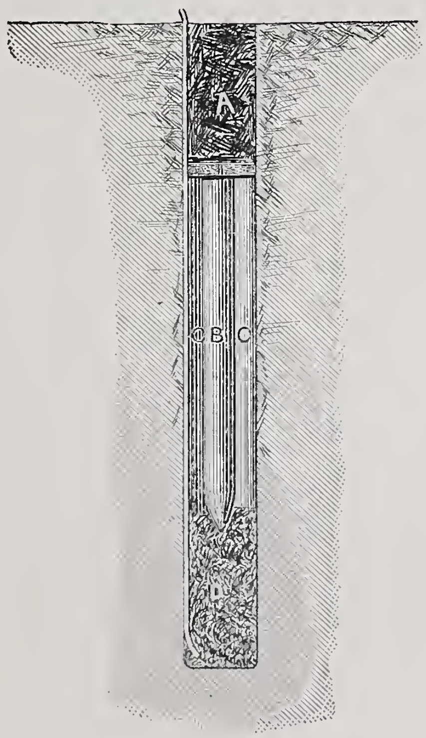
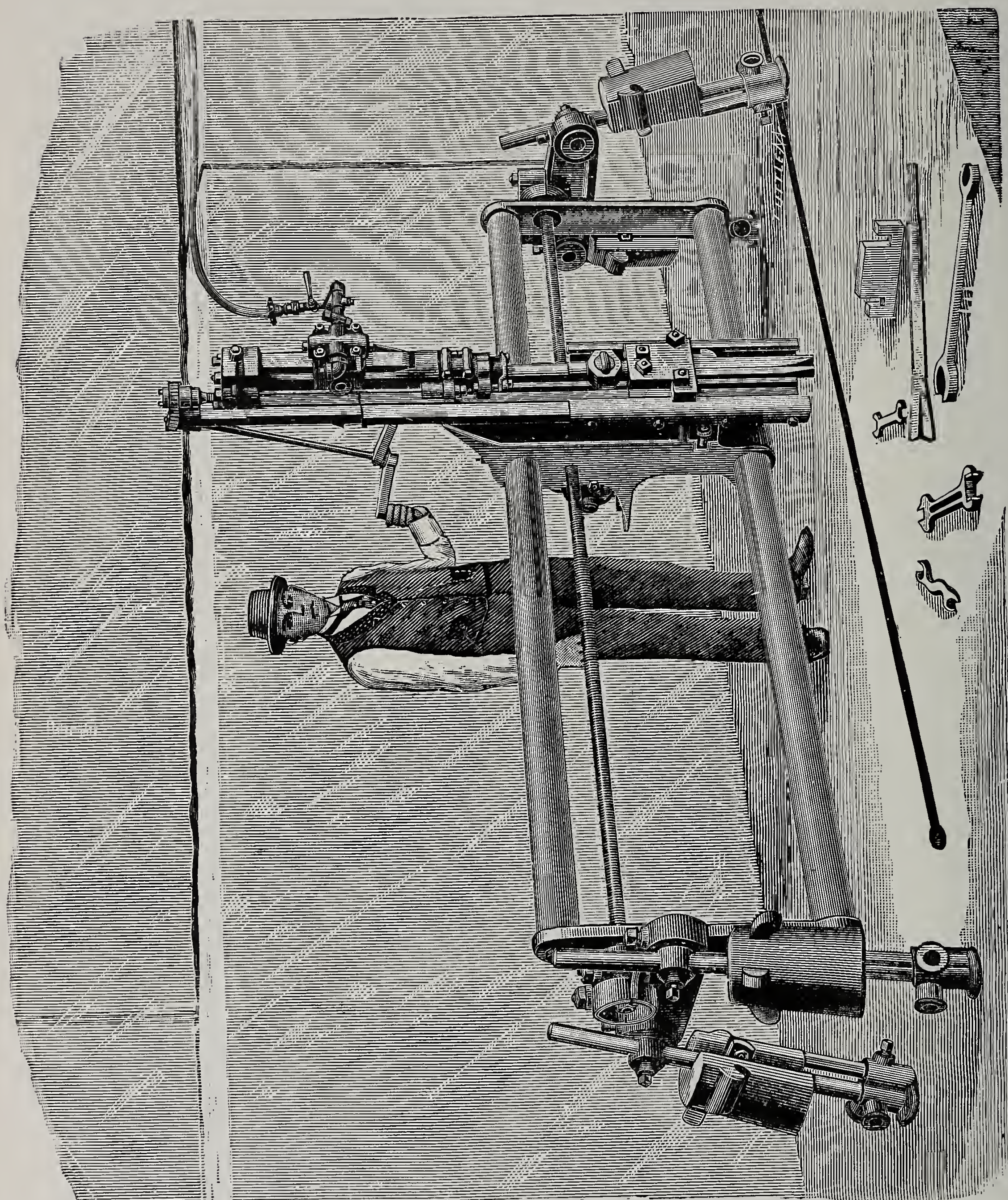


FIG. 11.

wad, which may be of oakum, hay, grass, paper, or other similar material.



BAR CHANNELER DRILLING A HOLE.

The tamping should be placed from 6 to 12 inches below the mouth of the hole. In some kinds of stone a less distance will suffice, and it is well to bear in mind that as much air space as practicable should intervene between the explosive and the tamping. Care should be observed in tamping not to destroy the wires which connect with the explosive, but the tamping should be made secure, so that it will not blow out. The hole is now ready for blasting. If several holes are used on a line they should be connected in series (Fig. 12) and blasted simultaneously by electricity. The effect of the blast is to

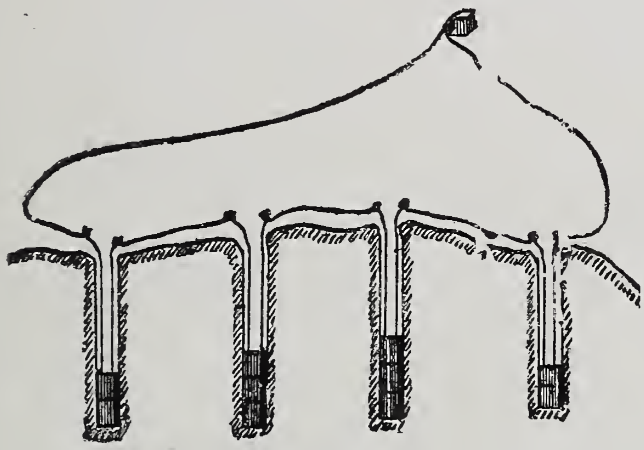


FIG. 12.

make a vertical seam connecting the holes, and the entire mass of rock is sheared several inches or more.

The philosophy of this new method of blasting is simple, though a matter of some dispute. The following explanation has been given. (See Fig 13.)

"The two surfaces, *a* and *b*, being of equal area, must receive an equal amount

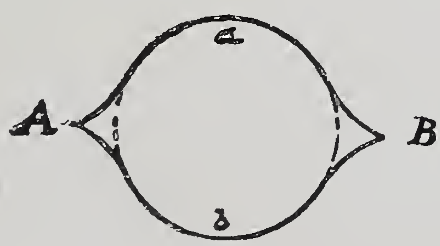
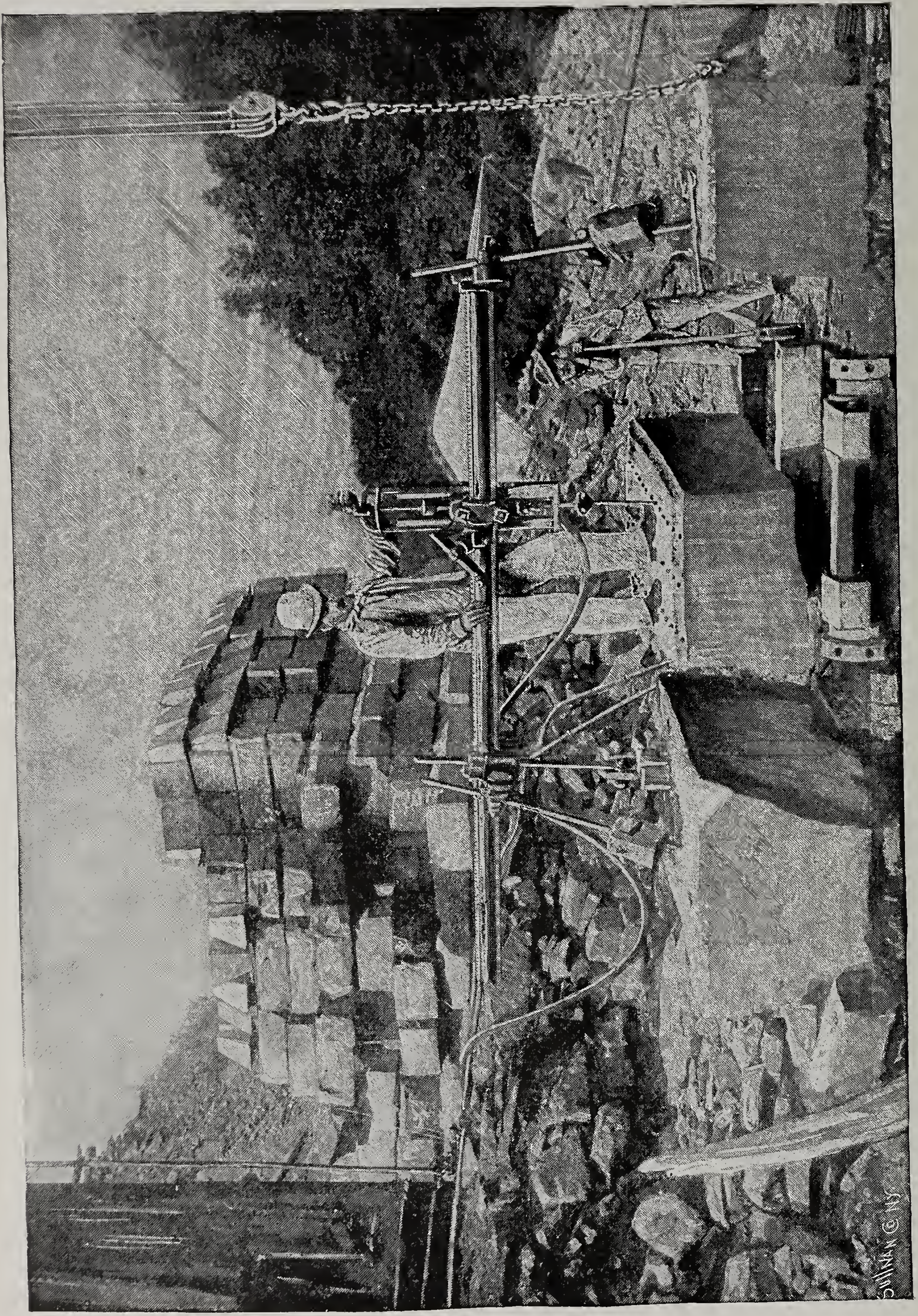


FIG. 13.

of the force generated by the conversion of the explosive into gas. These surfaces, being smooth and presenting no angle between the points *A* and *B*, furnish no starting point for a fracture, but at these points the lines meet at a sharp angle including between them a wedge-shaped space. The gas acting equally in all directions from the center is forced into the two opposite wedge-shaped spaces, and, the impact being instantaneous, the effect is precisely similar to that of two solid wedges driven from the center by a force equally prompt and energetic. All rocks possess the property of elasticity in a greater or less degree, and this principle being excited to the point of rupture at the points *A* and *B*, the gas enters the crack and the rock is split in a straight line, simply because under the circumstances it cannot split in any other way."

Another theory has been stated as follows : "A round hole forms on all sides a perfect arch, and, if the rock be sound, it is equally strong in all directions. The making of the grooves at opposite sides of the hole breaks the arch at these sides, thus producing two weak sides and two strong sides at right angles with each other. Force, being applied within the hole for the purpose of breaking the rock, naturally exerts itself in the lines of weakness which have been produced by destroying the arches at *A* and *B*, and they being exactly opposite to each other, the result is that the rock is fractured in a straight line, the gas generated by the explosion acting in these lines in the same manner as a line of wedges would if applied from the outer side of a rock, with this difference, viz., wedges applied from the outer side of a rock are driven inwards toward the point of greatest resistance in the rock, whilst the gas, being confined within the rock at its strongest part and operating toward the outside or weaker part, will naturally take that direction which will most quickly relieve the pressure, and that is a direct line to the surface."

The effect of the new system being practically the same as that of the old Portland system, or that of Lewising, it is natural that we should look into these systems in our efforts to explain why the rock breaks in a prescribed line. Good and true breaks have been made by Lewising, yet there is no V-shaped groove. Equally clear and efficient is the record of the old Portland canister, yet here, too, there are no V-



SPLITTING DIMENSION STONE AT THE QUARRIES OF THE BRANDYWINE GRANITE CO., WILMINGTON, DEL.

shaped grooves. It might be argued that the Portland canister, being imbedded in sand or other non-elastic material, forms a "wedge-shaped space," and here, too, "the gas is forced into the two opposite 'wedge-shaped spaces,' and, the impact being instantaneous, the effect is precisely similar to that of two solid wedges driven from the center by a force equally prompt and energetic."

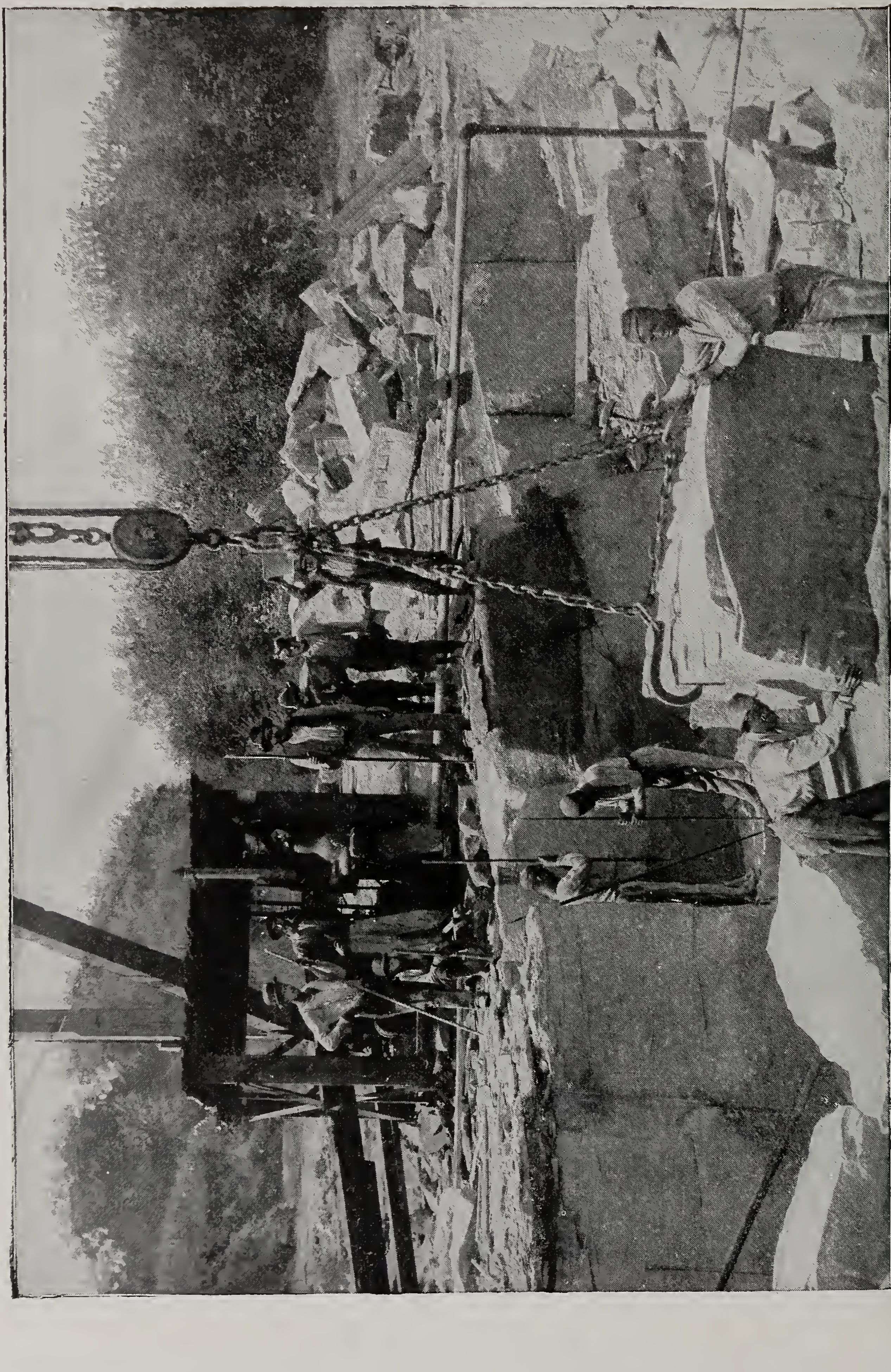
But we are met by the evidence of the Lewis hole, where there is no "wedge-shaped space." While it is doubtless true that the "wedge-shaped space" is an influence which assists the break, and that the breaking of the arch of the hole by the groove renders equally great assistance in that it produces a weak point to start the break, yet the main cause in the new form of blast which acts to direct the break is that the lines of force are exerted against the surfaces of the hole, *A b B* and *A a B*, to a greater extent than upon the surfaces *a A b* and *a B b*. In other words, there is a greater area of pressure acting toward *a* and *b*, and this naturally tends to produce a separation at *A* and *B*. The tension is precisely the same as that produced by a line of plugs and feathers, or a series of wedges driven in a trench.

Let us assume that an effort was made to split by the new form of holes without an explosion, but by using hydraulic or other pressure within the holes. It is obvious that, were we able to get the pressure high enough, the break would be made in the same way as though it were blasted, and the very purpose of the air cushion in the new system is to prevent the shock of the blast from having a bad effect upon the rock, and to confine the gas and air at a high pressure in the hole. The suddenness of the explosion is relieved by an expansion and compression of the air cushion, and it is the recoil of the energy after such compression which exercises the greatest force in breaking the rock. Notwithstanding the cushion, there is some shock, and this so far assists the break as to enable the operator to use but little explosive. Were the force exerted through hydraulic pressure, it would be advisable to produce a shock, just as a quarryman will strike a block of granite with a heavy sledge in order to start the break, while his plugs and feathers are under strain.

The new form of hole is, therefore, almost identical in principle with the old Portland canister, except that it has the great advantage of the shaped groove in the rock, which serves as a starting point for the break. It is also more economical than the Portland canister in that it requires less drilling and the waste of stone is less. It is, therefore, not only more economical than any other system of blasting, but it is more certain; and in this respect it is vastly superior to any other blasting system, because stone is valuable, and anything which adds to the certainty of the break also adds to the profits of the quarryman.

It is doubtless true that, notwithstanding the greater area of pressure in the new form of hole, the break would not invariably follow the prescribed line but for the V-shaped groove which virtually starts it. A bolt, when strained, will break in the thread, whether this be the smallest section or not, because the thread is a starting point for the break. A rod of glass is broken with a slight jar provided a groove has been filed in its surface. Numerous other instances might be cited to prove the value of the groove. Elasticity in rock is a pronounced feature, which varies to a greater or less extent, but it is always more or less present. A sandstone has recently been found which possesses the property of elasticity to such an extent that it may be bent like a thin piece of steel. When a blast is made in the new form of hole, the stone is under high tension, and being elastic it will naturally pull apart on such lines of weakness as grooves, especially when they are made, as is usually the case in this system, in a direction at right angles with the lines of least resistance.

Our previous illustration of a break by the new system was its simplest and best application. An identical case would be one where a large and loose block of stone was split up into smaller ones by one or more of this form of holes. But those who use this system



A QUARRY IN THE SOUTH.

do not confine it to such cases alone. Horizontal holes are frequently put in and artificial beds made by "lofting." In such cases where the rock has a "rift" parallel with the bed, one hole about halfway through is sufficient for a block about 15 feet square; but

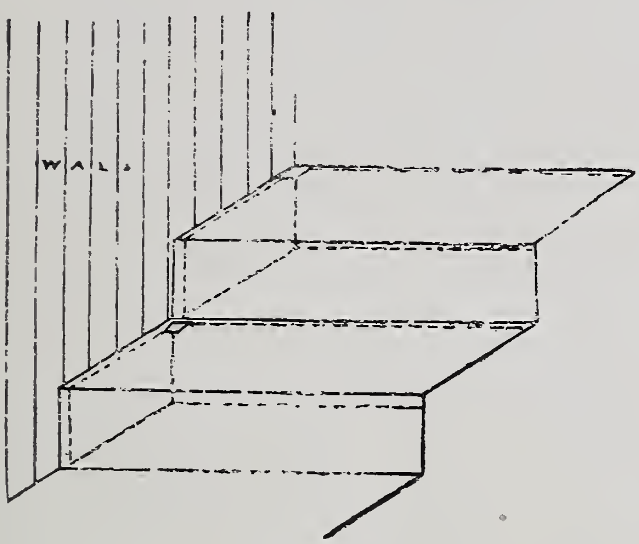


FIG. 14.

in "liver" rock the holes must be drilled nearly through the block, and the size of the block first reduced.

A more difficult application of the system, and one requiring greater care in its successful use, is where the block of stone is situated as in the case hereinbefore cited, except that both ends are not free, one of them being solidly fixed in the quarry wall. A simple illustration of a case of this kind is a stone step on a stairway which leads up and along a wall. Each step has one end fixed in the wall and the other free. Each step is also free on top, on the bottom, and on the face, but fixed at the back. We now put one of the new form of holes in the corner at the junction of the step and the wall. The shape of the hole is as shown in Fig. 14.

It is here seen that the grooves are at right angles with each other, and the block of stone is sheared by a break made opposite and parallel with the bench, as in the previous case, and an additional break made at right angles with the bench and at the fixed end of the block. Sometimes a corner break is made by putting in two of the regular V-shaped holes in the lines of the proposed break, and without the use of the corner hole. A useful application of this system is in splitting up large masses of loose stone. For this purpose the V-shaped grooves are sometimes cut in four positions, and breaks are made in four directions radiating from the center of the hole, as shown in Fig. 15. In this way a block is divided into four rectangular pieces.

Though the new system is especially adapted to the removal of heavy masses of rock, yet it has been applied with success in cases where several light beds overlie each other. In one such instance 10 sheets, measuring in all only six feet, were broken by a blast; but in cases of this kind the plug and feather process applies very well, and the new system, when used, must be in the hands of an expert, or the loss will be serious.

Referring again to our stone step, let us imagine a case where this stairway runs between two walls. We have here each step fixed at each end and free only at the top, the bottom, and one face. Let us assume that there is a back seam,—that is, that the step is not fixed at the back. In a quarry, this seam, unless a natural one, should be made by a channeling machine.

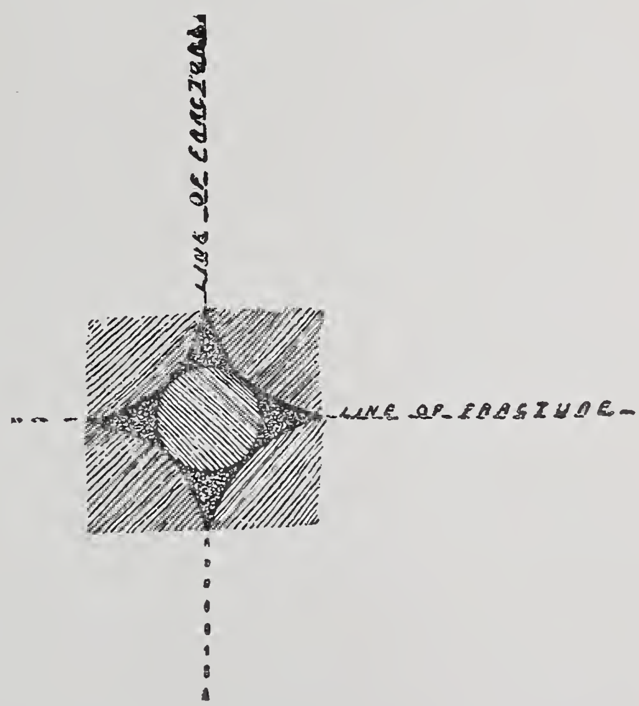
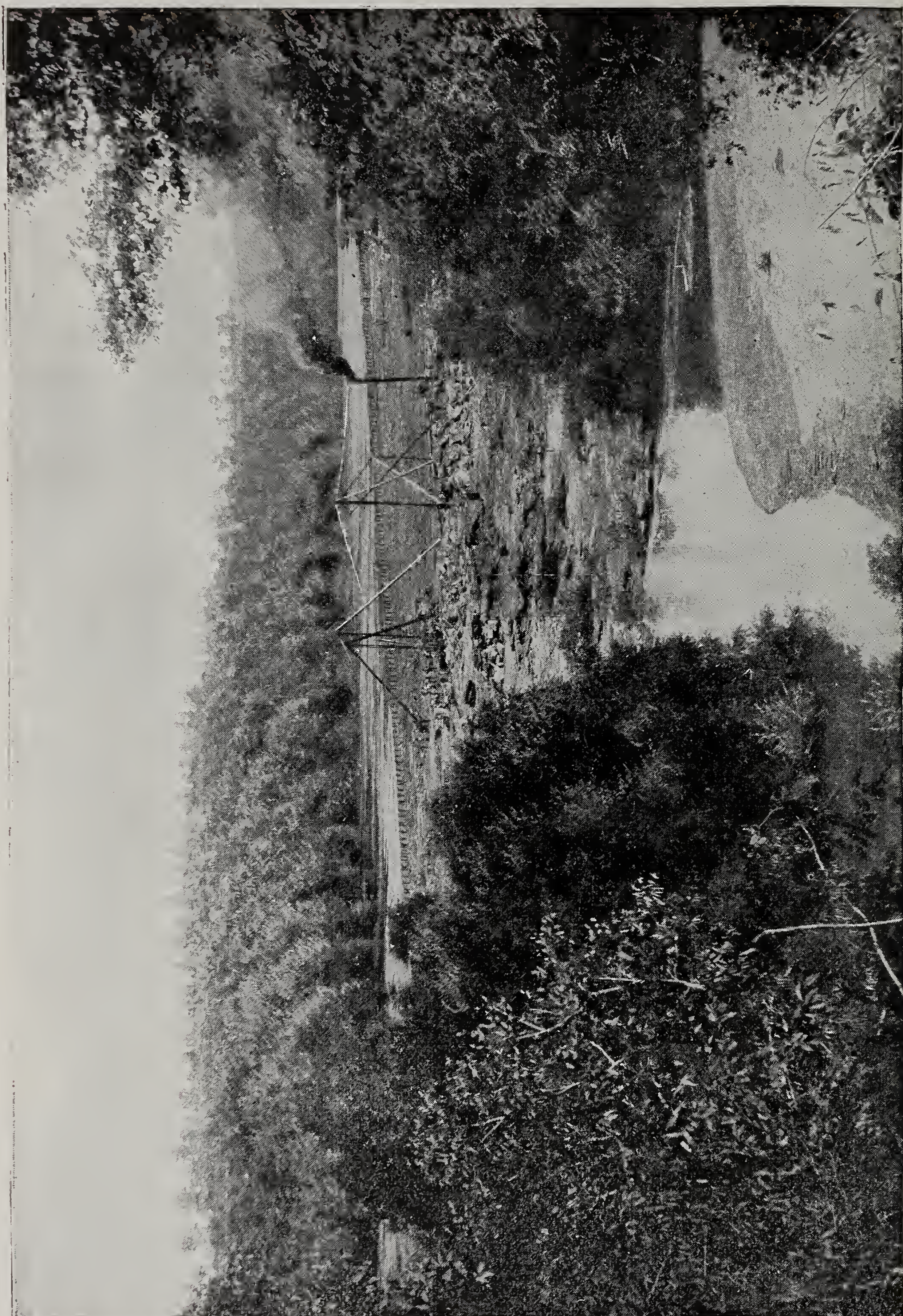


FIG. 15.

In order to throw this step out of place it must be cut off at both ends, and for this purpose the V-shaped holes are put in at right angles to the face. It is



A PICTURESQUE QUARRY.

well, however, to put the first two holes next the back seam in a position where the grooves will converge at the back so as to form a sort of key, which serves a useful purpose in removing the block after the blast. In quarries where there are no horizontal beds a channeling machine should be used to free the block on all sides and to a suitable depth, and then the ledge may be "lofted" by holes placed horizontally.

Where "pressure" exists in quarries, the new system has certain limitations. After determining the line of "pressure," it is only practicable to use the system directly on the line of thrust, or at right angles to it. It is much better, however, to release the "pressure" from the ledge by channeling, after which a single end may be detached by a Knox blast. It is well to bear in mind that the holes should invariably be of small diameter. In no case should the diameter of the hole be over 1½ inches in any kind of rock. This being the case, the blocks of stone are delivered to the market with but little loss in measurement. Every one knows that the buyer of a block of stone will figure its contents from the minimum measurement of its faces. A hole or groove at the top will shorten the measurement of the faces so that a good deal of stone may be quarried and even shipped to market without benefiting the quarryman, because it does not figure in the measurement. It is a noticeable fact that stone quarried by the new system shows very little evidence of drill marks, for the faces are frequently as true as though cut with a machine.

A matter of no little importance is the safety of the system. The blasting is light, and is confined entirely within the hole. No spalls or fragments are thrown from the blast; hence the blasts may be made safely within city limits.

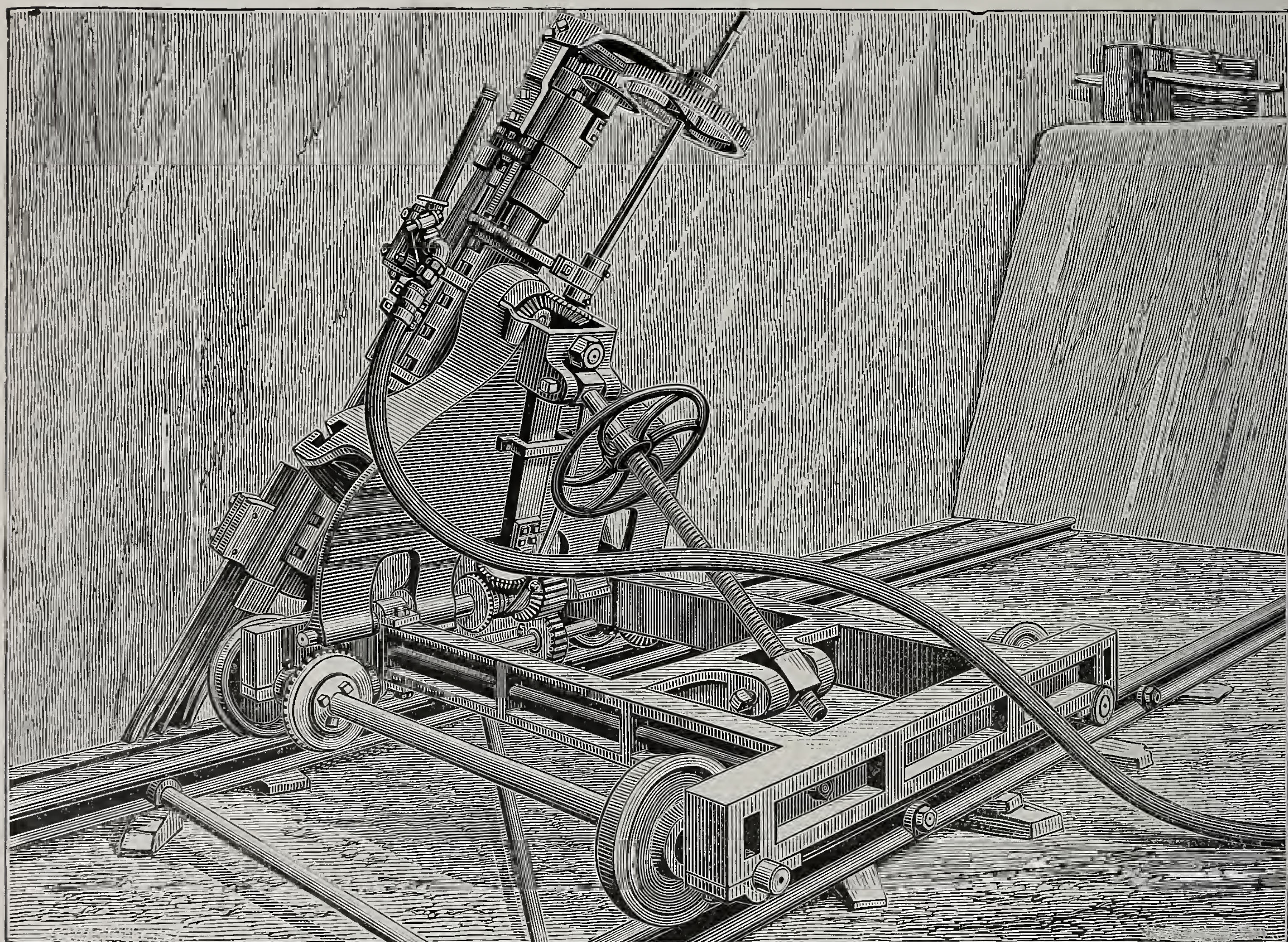
The popular idea that the system is antagonistic to the channeling process is a mistaken one. There are, of course, some quarries which formerly used channeling machines without this system, but which now do a large part of the work by blasting. Instances, however, are rare where the system has replaced the channeler. The two go side by side, and an intelligent use of the new system in most quarries requires a channeling machine. There are those who may tell of stone that has been destroyed by a blast on the new system, but investigation usually shows that either the work was done by an inexperienced operator, or an effort was made to do too much. Most good things are overdone. A quarryman who finds that a simple hole with a small amount of powder will release a large block in good marketable shape is very apt to carry his enthusiasm so far that he attempts to use the system in places where it is not suited. Blasts are made where there are not sufficient free faces, and a desire to avoid the expense of a channeling machine leads to the destruction of a valuable stone.

A most interesting illustration of the value of this system, side by side with the channeler, is shown in the Northern Ohio Sandstone Quarries. A great many channeling machines are in use there working around the new form of holes, and when used together in an intelligent and careful manner the stone is quarried more cheaply than by any other process that has yet been devised.

To a limited extent the system has been used in slate. The difficulty is that most of the slate quarries are in solid ledges where no free faces or beds exist; but it has been used with success in a slate quarry at Cherryville, Pa., since 1888. Among notable blasts made by this system are the following: At the mica schist quarries, at Conshohocken, Pa., a hole 1½ inches in diameter was drilled in a block which was 27 feet long, 15 feet wide, and 6 feet thick. The blast broke the stone across the "rift," only eight ounces of Dupont black powder being used. At the Portland, Conn., quarries and the Middlesex Quarry Company, a single blast was fired by electricity, 15 holes being drilled, with two pounds of coarse No. C powder in each hole, and a rock was removed 110 feet long, 20 feet wide, and 11 feet thick, containing 24,200 cubic feet, or about 2400 tons, the fracture being perfectly straight. This large mass of stone was moved out about two inches without injury to itself or the adjoining rock.

Another blast at Portland removed 3300 tons a distance of four inches. Seventeen holes were drilled, using two pounds of powder in each hole, the size of the block being 150 x 20 x 11 feet. In a Lisbon, Ohio, quarry a block of sandstone 200 feet long, 28 wide, and 15 feet thick was moved about a half an inch by a blast. This block was also afterwards cut up by this system into blocks six feet square. A sandstone bowlder 70 feet long, average width 50 feet, average thickness 13 feet, was imbedded in the ground to a depth of about seven feet. A single hole eight feet deep was charged with 20 ounces of powder, and the rock was split in a straight line from end to end and entirely to the bottom. A ledge of sandstone open on its face and two ends, 110 x 13 x 8 feet, was moved by a blast about three inches without wasting a particle of rock. Eight holes were drilled with a steam drill, three men being employed just one day, and 15 ounces of powder being used in each hole. A sandstone ledge, open on the face and end only, 200 x 28 x 15 feet, containing 84,000 cubic feet of stone, was moved half an inch by 25 holes, each containing one pound of powder.

The reports from the eleventh census show that in the year 1889 about $53,000,000 worth of stone was quarried in the United States. Ten years prior to that time, as shown by the tenth census, the annual output was $18,000,000. This enormous increase has been made possible by improvements in the quarry which have cheapened the production of stone. Who would not use stone for buildings of all kinds, and who does not prefer it to wood, brick, iron, or any other material? Its great cost alone prevents its almost universal use.



SCREW-FRAME CHANNELING MACHINE.

DRAWING-ROOM BEGINNINGS.

By A. G. Holman, Chief Draughtsman for Deane Steam Pump Co.

IN order to make a success it is necessary to take the tool or the plan by the right end, as well as to be careful in the right selection. When the success of a business is assured and the shops are extended and the working force increased, no argument for a drawing-room system is needed. The teachings of experience and the demands of business decide the case.

Judging thus from observation, and from the prevalence of articles on reconstruction, every enterprise has its dark ages, in which sketches, scratches, and jottings prevail; and this period is inevitably followed by what may be termed the reformation, in which the earlier work is carefully sorted, trimmed down to size or "lagged up" to size, numbered, indexed, and filed away with its more pretentious successors.

If improvements are found necessary in each individual case,—and all large mechanical enterprises now existing have passed through the transition referred to,—may we not generalize, and enter a plea for an improvement in beginnings, thus purifying the stream at its source rather than applying filters at its mouth?

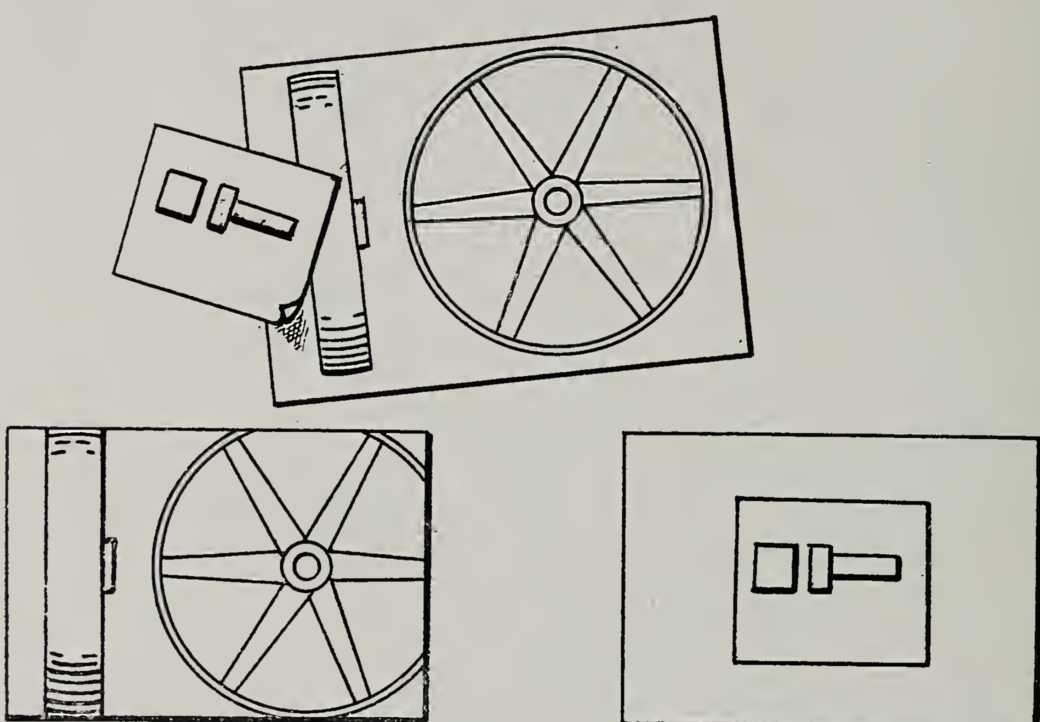
It is not presumed that many could be led to this desirable result by an appeal to their love of the beautiful or love for future generations. For the former the ordinary measure is its conformity to the American "line of beauty" ($). To the latter some one has already replied: "What do I owe to posterity? Posterity never did anything for me." Yet it is along these lines, in a slightly different sense, that good grounds may be found for a systematic beginning.

It pays to make accurate drawings, because it is cheaper to try experiments on paper than in metal; and when the designs are made it pays to keep them, because they are an invaluable record of early work, for legal purposes, for repairs, and for comparison.

In view of the rapid developments of this age, it is also well to consider in our pioneer work the needs of those who manage its later stages, for we are liable to come into the inheritance ourselves. The manager seldom has the time to properly follow the details of the drafting room; but he should find time to secure a man, and a good one, who can give it his entire attention. Such men are now available, and they are as willing to faithfully lay the foundations as to reconstruct and build upon them when their services are called for at a later period.

It cannot be said that the teaching of our schools emphasizes very strongly the details of drawing-room management. This may be from the supposition that this, with many other practical matters, will be learned by experience. But for various reasons the responsibilities of the situation often fall upon young shoulders, and the experience which follows is of that kind which supplies the material for continued reorganization. If an agreement can be reached between managers, draftsmen, teachers, and students upon a few of the underlying principles, a change will be made at the principal fountain-heads. It is therefore hoped that if the suggestions which follow do not furnish a basis for perfect agreement, they may at least bring other helpful plans to the surface.

Materials.—In general, the drawing-room supplies should be of such a nature as to provide for the reproduction of drawings by blue printing or other analogous process. It is an expensive luxury to put the product of time and brains on a triangular scrap of brown paper, or to save a tracing by sending an original drawing into the shop. A good tracing for reference and a print for shop use is true economy. Usually a real saving may be made by omitting the ink on the paper drawing,—merely sketching upon that medium and completing the work upon the tracing. In special cases, when frequent handling is liable to injure the tracing, an extra copy for drawing-room use may be taken.



ORIGINAL AND "REFORMED" SPECIMENS.

Size of Drawings.—It is not practicable, as a rule, to bring all drawings to a single standard size. In this attempt three difficulties will be encountered: First, the details of a complicated piece will be confused by the small scale required to accommodate the sheet of medium size; second, it will be found that a simple detail must be placed like an oasis on the broad expanse; or, thirdly, by attempting to utilize the space numerous details must be huddled together upon one sheet, with resulting inconvenience in its use. A series of three sizes of sheets, named for convenience of reference the large, the medium, and the small sheet, is recommended. The large sheet should not be too cumbrous for handling,—say 16 x 24 inches. For the medium size use one-half of the large sheet, or 12 x 16 inches, and for the small sheet in the same manner halve the medium size, giving a sheet 8 x 12 inches.

Classes of Drawings.—While each business has its distinctive features, which cannot be dealt with in a general article, there are certain conveniences which seem to fit nearly all cases. One of these is the Assembly sheet. This contains a graphic collection of the details to represent the entire machine, a list of sizes and numbers of drawings containing details, the pattern numbers and number of castings, etc., required.

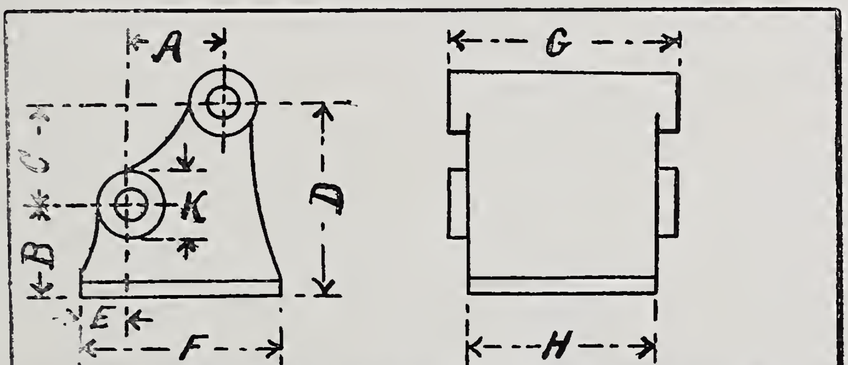
A WORKING DRAWING.

Another useful sheet is the tabular drawing, which can usually be one of the smaller sizes. This contains an outline drawing with reference letters in place of dimensions, and a table in which these dimensions for given sizes of work are stated. Such tables, judiciously used at the outset, will save many more expensive drawings and the unnecessary increase of patterns.

Lettering.—The title of a drawing is an important item. It should be prominent and legible. The letters on all drawings should be of uniform style and size, preserved by reference to a copy or by the use of rubber types. The titles should also have a uniform position upon the sheet.

tions will be necessary to read them all, and one of these positions should be the same as required for reading the title. The last suggestion may seem unnecessary unless you have watched a workman making a few revolutions around a go-as-you-please drawing.

Filing.—Now that the sheets have been selected, and the drawings made and numbered, what shall be done with them? The way of the dark ages was to provide a few deep drawers into which the drawings were sorted according to kind, and were afterwards excavated in much the same way that an article is produced from the depths of the small-boy's pocket. The modern method, however, is to use cases of shallow



	A	B	C	D	E	F	G	H	K
4 × 5									
7 × 10									
9 × 10									

A TABULAR DRAWING.

Numbering.—All sheets should be numbered consecutively without reference to size, so that if the size is not mentioned in correspondence no confusion can result. The number should be placed with date and scale under the title of the drawing, and should also be marked conspicuously on two corners, so that when filed away the number will be easily found. The accompanying cut indicates the method of numbering and also the position of titles.

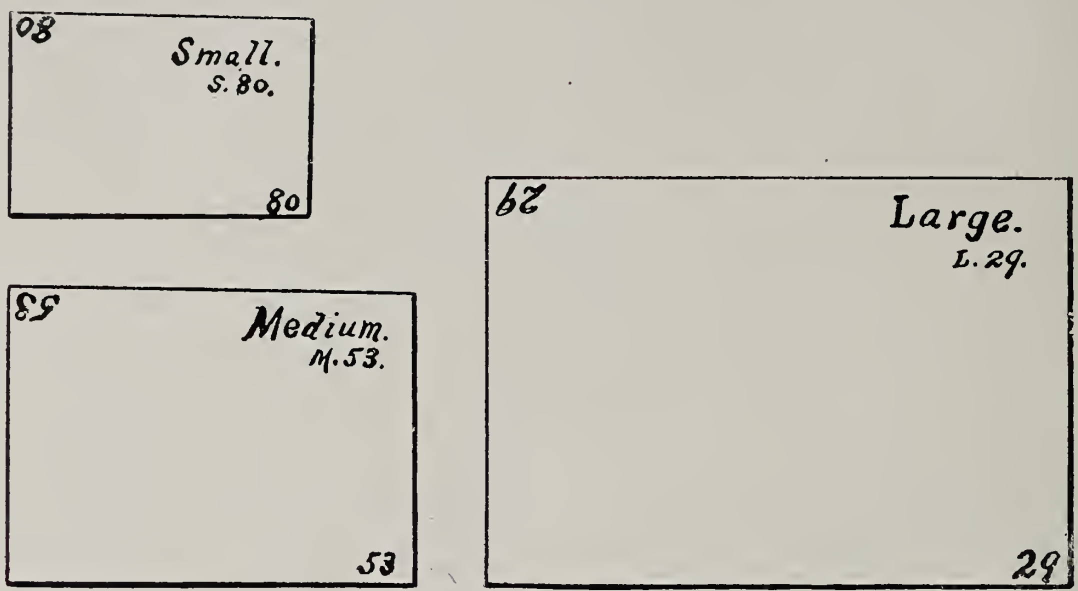
Figures.—All dimensions should be given in figures, leaving nothing of importance to be determined by scaling. The figures should be of good size. The dividing line of fractions should be horizontal, not oblique. All dimensions should be so placed that only two posi-

drawers, a trifle larger than each size of sheet, and deep enough to receive about fifty drawings each. The drawings are put away strictly according to number, smaller numbers at the top, and the drawer-front is prominently marked with smallest and largest numbers contained therein.

Indexing.—The index of drawings, like the drawing case, has been through a process of evolution. First, with a few sheets, the attempt is made to let them serve as their own index by a classification of drawings. This is soon outgrown, and usually the next step is the numbering of drawings and the opening of an alphabetically indexed book. Or possibly a set of large cards, arranged by kind and filled up as draw-

ings are made, is the next resort. As no provision can be made in these methods for strict classification by size of work, it soon becomes a tedious process to hunt down a given drawing. But when the drawings are all systematically disposed of by number it is really but a step to complete the work, for it is identical in principle with the indexing of a library. In one case it has to deal with names of machines, sizes, and perhaps customers and places. In the other it is names of books, subjects, and authors.

In both cases an entirely satisfactory index, and the only one fully meeting the requirements, is the card catalogue. Small cards are filled out, referring to each drawing, one stating the kind and size; another, if necessary, referring to customer or place connected with the work. If several pieces are drawn upon one sheet, all are thus separately entered on the cards, all cards giving number and size of drawings. The cards are then placed alphabetically in a suitable case. Cards referring to the same kind of pieces will, of course, come together in the case, and are further arranged according to the size of machine or piece referred to. Hence the index is always perfectly arranged, and is ready to instantly give information as to what styles and sizes of work have been made, what machines certain parties have had, and where all details may be found.



TITLES AND NUMBERS.

As large drawing rooms have all found that thoroughly systematic work is necessary, and as small drawing rooms are growing into large ones, it follows that by a little care in the timely selection of methods a systematic and continuous plan from the beginning may be secured at less expense than when fully introduced at a later period.

THE STEAM ENGINE.*

By W. H. Laurie, Mem. Can. Soc. C.E.

IN tracing up the history of the steam engine, considered as a train of mechanism, we find that the modern steam engine has been fully developed within the last 200 years, or since the year 1690, and its advance during that time, may be divided into four stages or periods of 50 years each.

First Stage or Period—1690–1740.—As a rule, the great majority of inventions when first introduced to the public are more or less complicated and cumbersome, the object of subsequent improvements being to simplify and reduce the number of parts. To this rule the steam engine forms a striking exception, it having been first introduced in its simplest form, each consecutive stage in its history being marked by an increase in the number of its parts and in the complication of its construction, and a corresponding reduction in the consumption of steam per horse-power.

About the year 1690 Denys Papin invented the first steam engine, or rather steam cylinder with a piston. When first introduced the cylinder performed the functions of steam boiler, steam cylinder, and condenser. It was operated as follows : A small quantity of water was placed at the bottom of the cylinder, a fire built beneath it, the steam formed raising the piston to the top of the cylinder, where a latch engaged a notch in the piston-rod holding it up until it was desired that it should drop.

The fire being removed, the steam condensed, forming a vacuum below the piston. The latch being disengaged, the piston was driven down by the pressure of the atmosphere, raising a weight which had been in the meantime attached to a rope from the piston-rod over pulleys. This machine made *one stroke* per minute. The inventor calculated that a 24-inch cylinder would raise 8000 pounds four feet per minute, or develop nearly one horse-power.

A few years after his first invention Papin made another important invention, which increased the efficiency of his engine, by using a separate steam generator,—as described at the time, a kind of fire-box steam boiler, in which the fire, completely surrounded by water, made steam so rapidly that his engine could be driven at the rate of four strokes per minute by the steam supplied from it.

The Papin engine was further improved and developed by Newcomen, Beighton & Smeaton, producing a combination of several of the elementary parts of the modern engine, making it capable of transmitting force directly to the resistance to be overcome, the object being to adapt it to pumping mines, etc. The piston was connected to the pump by means of an overhead beam.

During the first period of development the steam engine was used almost entirely as a pumping machine, and might more properly be considered an atmospheric engine, as steam was used only to produce a vacuum, the power being supplied by the pressure of the atmosphere, and that on one side of piston only.

Second Period — 1740–1790. — The second stage or period in the development of the steam engine may be considered as entirely the work of James Watt (that stage being marked by more rapid development than any other). He, among many other important inventions and improvements, added to the engine of the first period the separate condenser, air pump, fly-ball governor, crosshead, guides, parallel-motion, rotary-motion, double-action, and non-condensing high-pressure steam engine. With these additions

* Paper read before the Canadian Society of Civil Engineers.

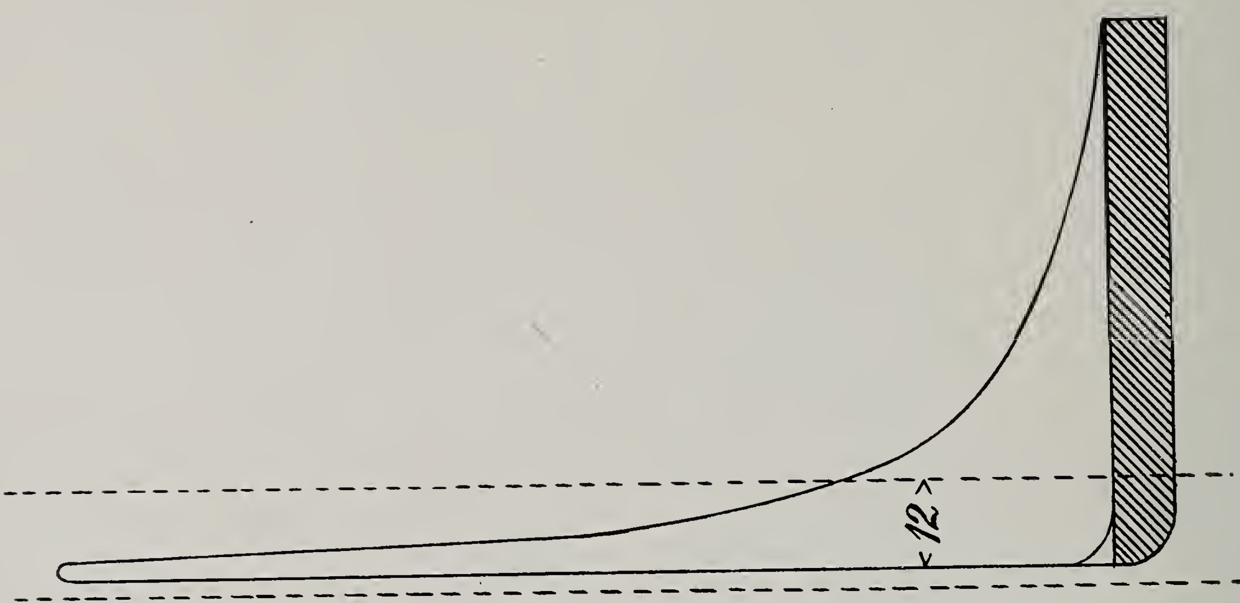
the machine embodied nearly all of the essential features of the modern engine. He also discovered the advantages to be derived from the use of steam expansively, and specified a cut-off at ¼ stroke as the most economical. This discovery has proved to be most important in the development of the economical application of steam, although shortly after its first introduction it had to be discontinued, owing to the trouble and annoyance Watt experienced with proprietors and their engineers altering the valves. He intended to resume it at a later period when workmen of greater intelligence and reliability could be found.

Third Period—1790–1840.—The distinguishing feature of the third period was the introducing of the compound or two-cylinder engine. Although the first compound engine was invented in 1781 by Jonathan Hornblower, it was not a success, owing to the steam pressure used at that time being so low that no advantage was gained by the device.

In 1804 the Hornblower compound engine was again introduced by Arthur Woolf, and, by using steam at a higher pressure and expanding it from six to nine volumes, a very great advantage was gained over the Watt and other engines of that time. Other engineers followed in Woolf's footsteps, designing modifications of the compound engine, so that by the end of the third period which we have considered the compound had become a standard engine.

Fourth Period — 1840–1890. — The most important features in the development of the economical use of steam during the fourth period, or that of the immediate past, has been the invention and introduction of the automatic engine, and the system of expansion (in two cylinders during the former period) being carried to three or four cylinders.

The first automatic engine was invented by George H. Corliss, about the year 1850. An adjustable drop cut-off had been invented ten years earlier by F. E. Sickels, but Corliss was the first to attach the governor directly to the cut-off mechanism, and, by so doing, regulate the speed of the engine by adjusting the point of cut-off, and also using steam in the cylinder at



nearly boiler pressure up to that point. To form an idea of the advantages of modern steam practice as compared with that of the earlier stages of its use, and to note the advance made during the four different stages we have considered, we shall assume an average indicator card for each period from the information we have, and, by analyzing each, form a comparison.

For that purpose we shall assume a steam cylinder of 13⅝ inches diameter, or a net area of 144 square inches in each, and for the first period a gage pressure of one pound or 16 pounds absolute.

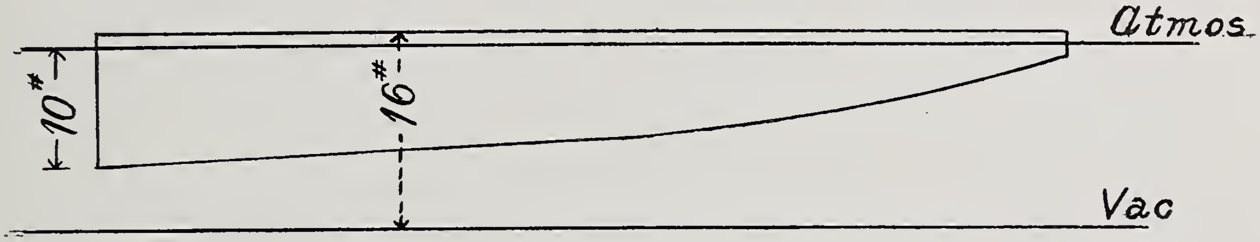
Allowing one pound to raise weight of piston-rod, etc., and that a vacuum be produced equal to a M. E. P. of seven

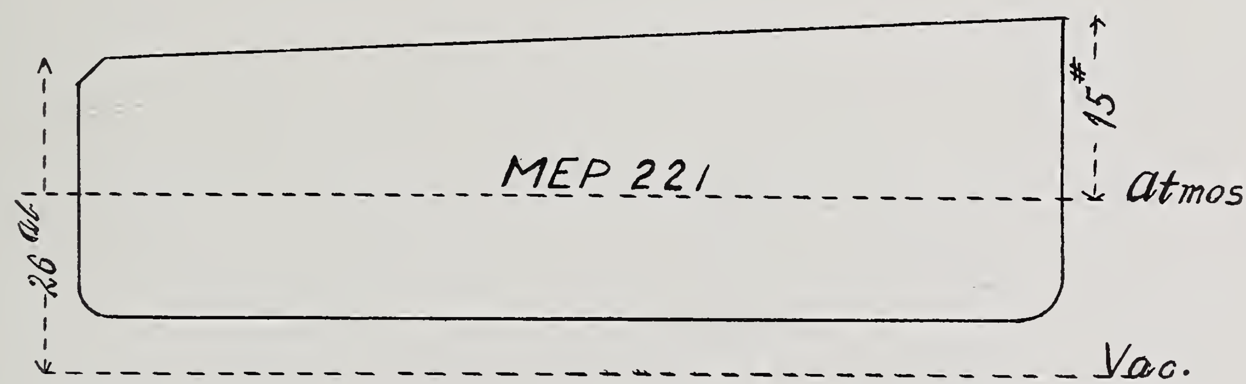
pounds below the atmospheric line, and allowing a piston travel of 100 feet per minute, the power developed will be 144 × 100 × 7 = 100,800 ÷ 33,000 = 3.05 horse-power, and the theoretical consumption of steam will be 100 cubic feet per minute or 6000 cubic feet per hour, and as steam at 16 pounds absolute weighs .0411 per cubic foot, then 6000 × .0411 = 246.6 pounds of steam per hour, and as we have found that the power developed will be 3.05 horse-power then 246.6 ÷ 3.05 = 80.85 pounds of steam per hour per horse-power as the consumption for the first period.

= 40 pounds of water per hour per horse-power for the second period, or about one-half of that required to develop a horse-power 50 years earlier.

For the third period a still higher steam pressure was used, and expansion carried to six and nine volumes.

For this card we will assume, same cylinder area, 400 feet piston travel, 40 pounds steam pressure, expanded 7½ volumes, and a M. E. P. of 16 pounds. The power developed will be 144 × 400 × 16 ÷ 33,000 = 27.93 horse-power, and the steam consumption measured from terminal of nine pounds will be 400 × 60 = 24,000 × .0239 ÷ 27.93 = 20.5 pounds





For the second period with same cylinder area we will assume 200 feet of piston travel. (Steam at this period was used above atmospheric pressure, and double-acting.)

For this card we will assume a steam pressure of 15 pounds and a terminal of 26 pounds absolute, a M. E. P. of 22.4 pounds. The power developed will 144 × 22.4 × 200 ÷ 33,000 = 19.5 horse-power, and the amount of steam consumed will be 200 cubic feet per minute or 12,000 cubic feet per hour; and as steam at the terminal pressure, viz., 26 absolute, weighs .0650 per cubic foot, then 12,000 × .0650 = 780 pounds per hour; this divided by 19.5

of steam per hour per horse-power, or about one-half of the cost of same power during second period, and one-fourth of cost of same power during first period.

For the fourth and last period of steam-engine practice we have in many instances a steam pressure of 200 pounds, also cylinder steam-jacketed with superheated steam, and other refinements that tend to reduce steam consumption.

For this period we will assume a steam pressure of 150 pounds, expanded 20 volumes, a M. E. P. of 31 pounds referred to same cylinder area as in other cards, viz., 144 inches, and

a piston travel of 800 feet. This will develop 108 horse-power, and the steam consumption will be about 10 pounds per hour per horse-power.

In reviewing these four periods, we have in the first steam used at a little over atmosphere pressure, without expansion, a piston travel of 100 feet per minute, a power developed of 3.05 horse-power, at a cost of 80 pounds of steam per hour per horse-power.

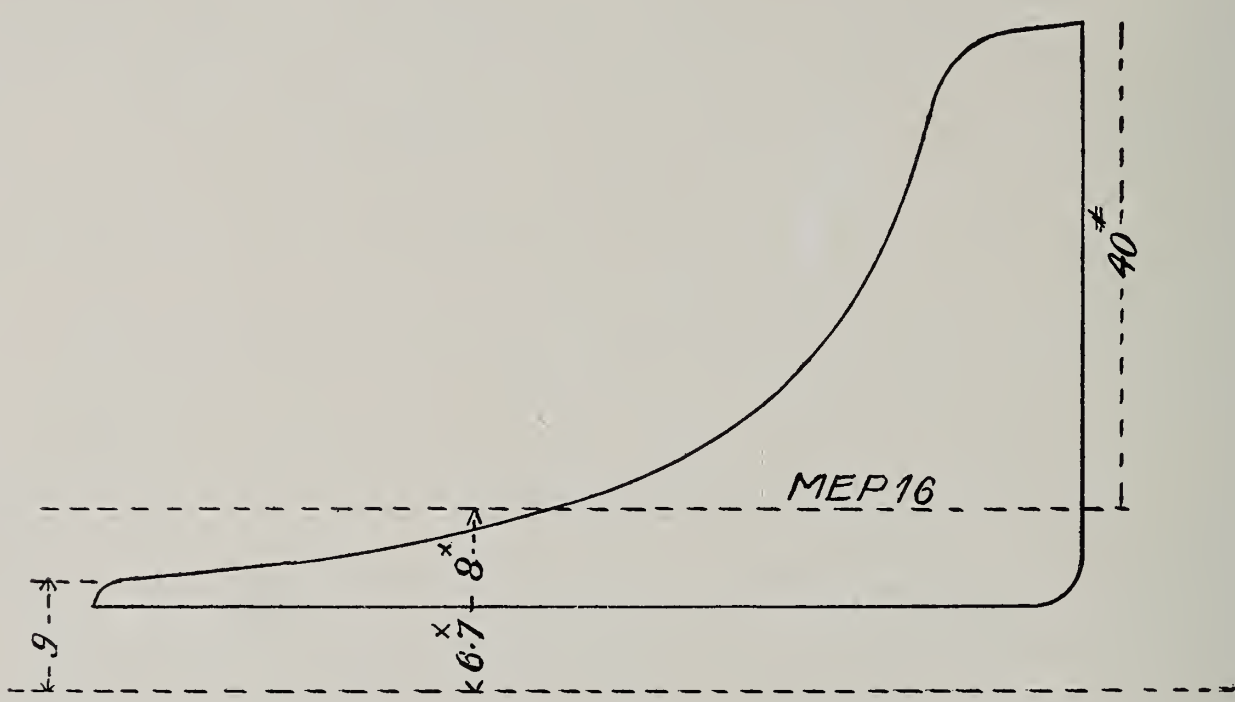
In the second period we have steam at 15 pounds above atmosphere, without expansion, a piston travel of 200 feet per minute, a power developed of 19.5 horse-power, with a steam consumption of 40 pounds per hour per horse-power.

In the third period we have steam at 40 pounds above atmosphere, expanded to 7½ volumes, a piston travel of 400 feet a minute, a power developed of 27.93 horse-power, with a steam consumption of 20 pounds per hour per horse-power.

And in the fourth period we have steam at a pressure of 150 pounds above atmosphere, expanded to 20 volumes, a piston travel of 800 feet per minute, and a power developed of 108 horse-power, with a steam consumption of 10 pounds per hour per horse-power.

From figures in table we find that the tendency through all the different periods has been increased steam pressure and higher ratio of expansion, or high initial and low terminal,—*i. e.*, theoretically the higher the initial and the lower the terminal the greater the economy. But practice has established it to be a fact that the higher the initial and the lower the terminal, or the greater the ratio of expansion in a *single cylinder*, the greater the loss both by *clearance* and *condensation.*

Cyl. Area.	Pist'n tr'el.	St'm P.	Power.	The'r'tical Cons'ption.
1st 144	100	1	3.05	80 lbs.
2d........ "	200	15	19.5	40 "
3d........ "	400	40	28.0	20 "
4th. ..... "	800	150	108.0	10 "



Clearance is the space between the piston and valve face when an engine is on its center (including area of ports, passages, etc.), which has to be filled with steam each stroke before the piston moves forward, and is computed by the percentage its volume bears to the area of piston multiplied by the length of its stroke. This varies from two per cent. in long-stroke engines to 15 and even 20 per cent. in short-stroke engines.

The loss by clearance is quite a serious one where expansion is carried to extremes in a single cylinder, and

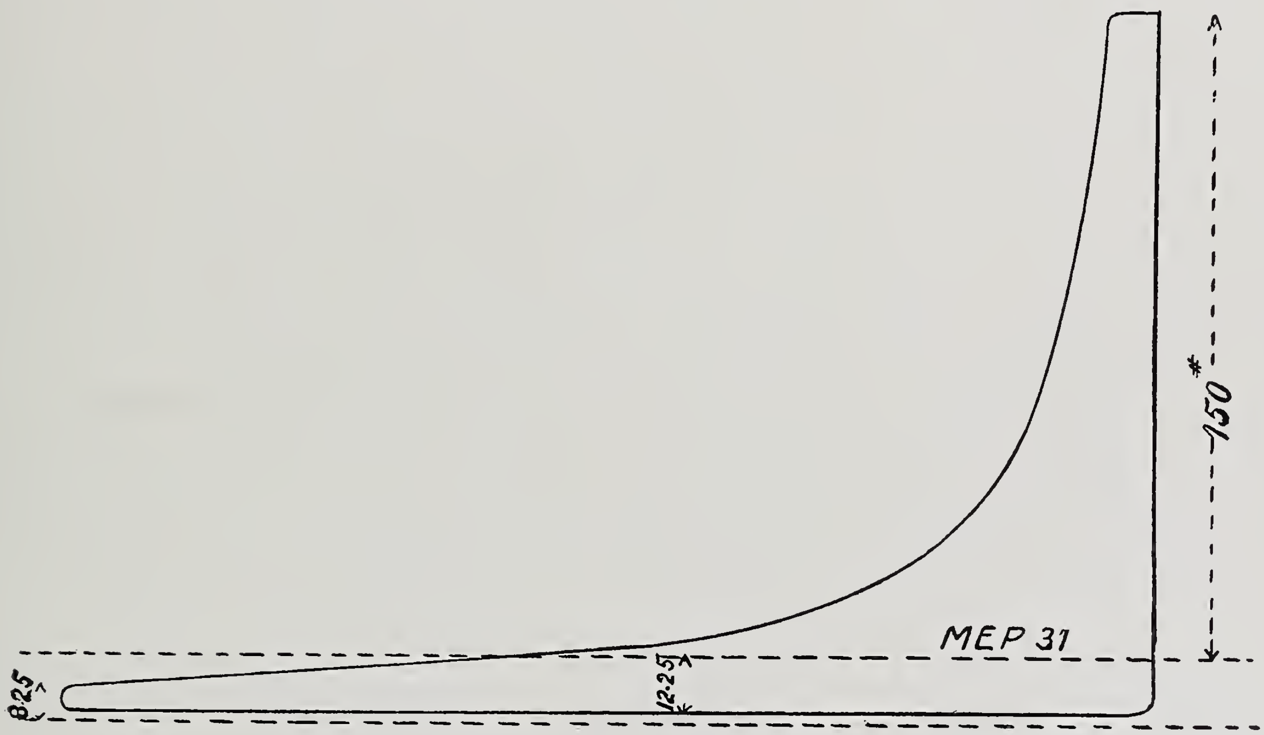
also in short-stroke engines, where it forms a high percentage of the volume of cylinder.

If we take as an illustration a condensing-engine card, with steam pressure 80 pounds, expanded 20 volumes without loss by clearance, we get a mean effective pressure of 15 pounds.

Then expand the same volume of steam in a cylinder of same area, but with five per cent. clearance. We find that the card shows the steam to have been cut off at the time the engine was on its center; we get the same expansion line and same terminal, but the area does not include that at initial pressure, or a mean average pressure to a certain extent, but not entirely overcome by compression or cushion.

Condensation.—The loss by condensation is due to the variation in the temperature of steam during expansion. If steam at 80 pounds gage pressure, or 95 absolute, be expanded 20 volumes, the initial temperature would be 324 degrees Fahrenheit and the terminal about 160 degrees.

During expansion, as the temperature of the steam falls, the temperature of the metal of the cylinder falls in proportion, so that when the boiler pressure is again admitted to the cylinder it takes a certain proportion of the steam admitted to raise the temperature of the



of 10.5 pounds instead of 15 pounds, as in the first instance, representing a loss of 30 per cent. in power.

Then, again, if the same pressure, viz., 80 pounds, be expanded 10 volumes, the loss is reduced to 16.66 per cent.; expanded five volumes, the loss is reduced to 9.75 per cent.; and if only expanded three volumes, the loss is reduced to about seven per cent.

Therefore the greater the ratio of expansion in a single cylinder the greater the loss by clearance, and the less the expansion in a cylinder the less the percentage of loss by clearance. The loss by clearance may be reduced surrounding metal to the initial temperature; the greater the ratio of expansion the greater the variation in temperature in the cylinder, and the greater the proportion of steam required to raise that temperature; the less the expansion in a cylinder the less the variation of temperature, and the less steam will be condensed in raising that temperature each stroke; or the smaller the volume of steam admitted to the cylinder each stroke the greater will the percentage "of loss by condensation" bear to that volume, and, on the other hand, the greater the volume of steam admitted to the cylinder each

stroke the less will the percentage "of loss by condensation" bear to that volume.

From experiments carried out these losses have been computed approximately for unjacketed single-cylinder engines with low percentage of clearance, as follows, viz.:

Expansions.	Power.	Loss.
20	55 p. c.	45 p. c.
10	65 "	35 "
5	75 "	25 "
3	80 "	20 "
2	85 "	15 "

With five per cent. added for condensing engines.

Another serious objection to high ratios of expansion in a single cylinder is the very great variation in the working strains throughout the stroke. For example, if we expand 80 pounds steam pressure to 20 volumes in a single-cylinder condensing engine, we have a pressure of 92 pounds per square inch of piston at the beginning of the stroke, 1.75 pounds at the end of the stroke, and a M. E. P. of 15 pounds, and as the strength of an engine in all its working parts must be in proportion to the greatest pressure to which it is subjected, then the weight of the working parts must be entirely out of proportion to the power actually developed, and the fly-wheel especially must be very much heavier than that required in an engine where steam is expanded from three to five volumes.

The theoretical gain by expansion in a condensing engine is approximately as follows, taking 80 pounds gage pressure without expansion as a basis:

Expanded to	20	volumes,	70	per cent.
"	10	"	65	"
"	5	"	60	"
"	3	"	50	"
"	2	"	40	"
"	1⅓	"	20	"

To obtain the economical advantages resulting from high ratios of expansion, and at the same time avoid the enormous losses attending its expansion in a single cylinder, is the object of the introduction of the compound, triple, and quadruple expansion engines. For example, in a compound engine with low-pressure cylinder four times the area of high pressure, 16 expansions may be obtained with four expansions in each cylinder. In this way the high-pressure cylinder works with steam between limits of temperature, such as occasion comparatively small losses by condensation, and the low-pressure cylinder works between the temperature of the exhaust from high pressure and that of the condenser; these temperatures not varying very widely, the loss by condensation is correspondingly small. Another great advantage of the compound over that of the single-cylinder engine (expanding steam to the same number of volumes) is the better distribution of the work throughout the stroke, admitting of the working parts being made much lighter in proportion to the actual power developed.

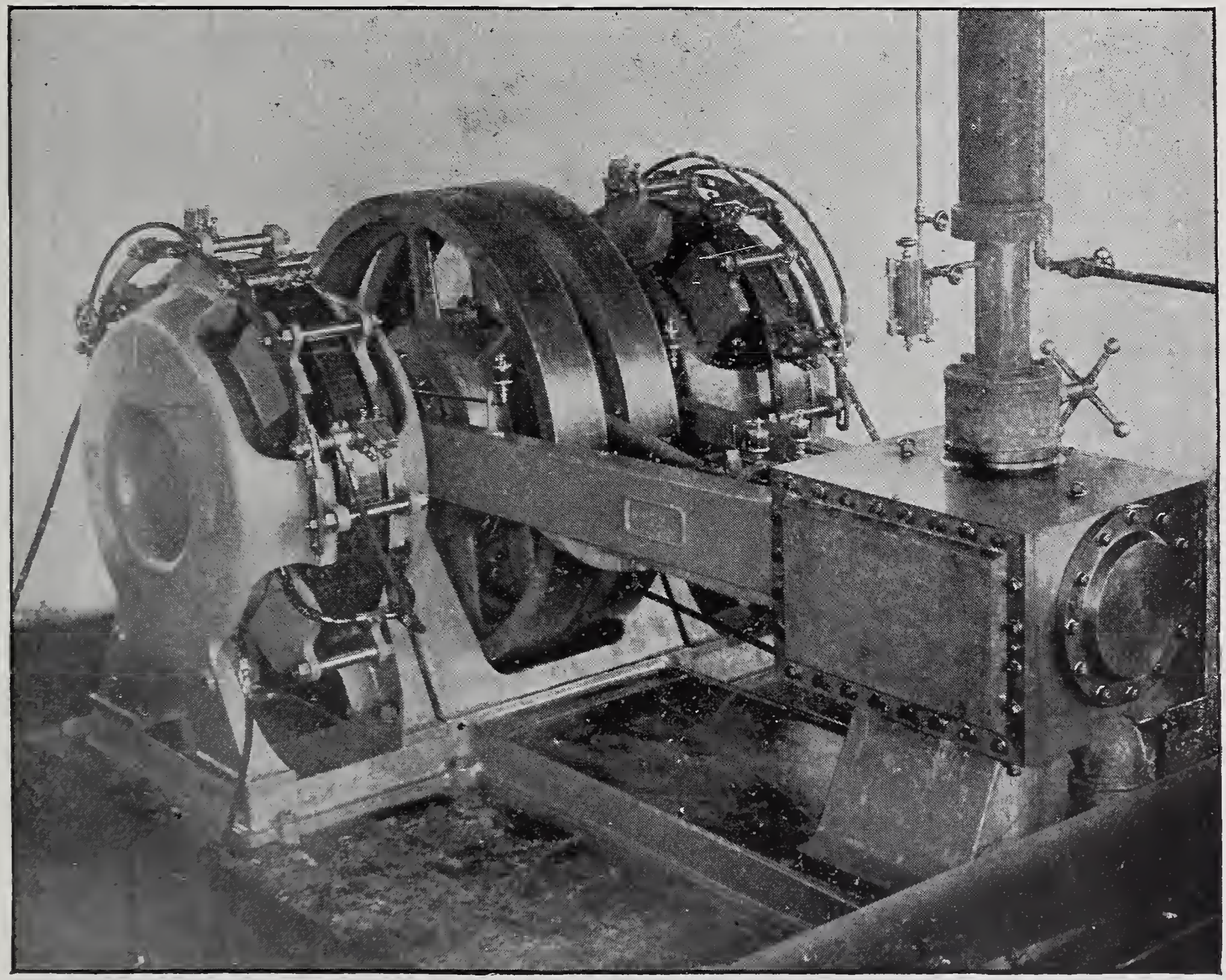
It would almost appear as if the economical limit in expansion had been reached, as by our example for the last period the theoretical consumption for 150 pounds expanded 20 volumes was 10 pounds of water per hour per horse-power, whereas if we raise the pressure to 200 pounds and expand 30 volumes, the gain is only about five per cent.; if raised to 400 pounds and expanded 40 volumes, the gain is about 20 per cent., and if to 800 pounds expanded 40 volumes, about 25 per cent.

But to counteract this apparent gain, we have increased coal consumption in raising the water to the temperature due to the increase of pressure, and also increased losses by condensation in using steam at that temperature.

DIRECT-CONNECTED ENGINES.—IV.

By Charles H. Werner.

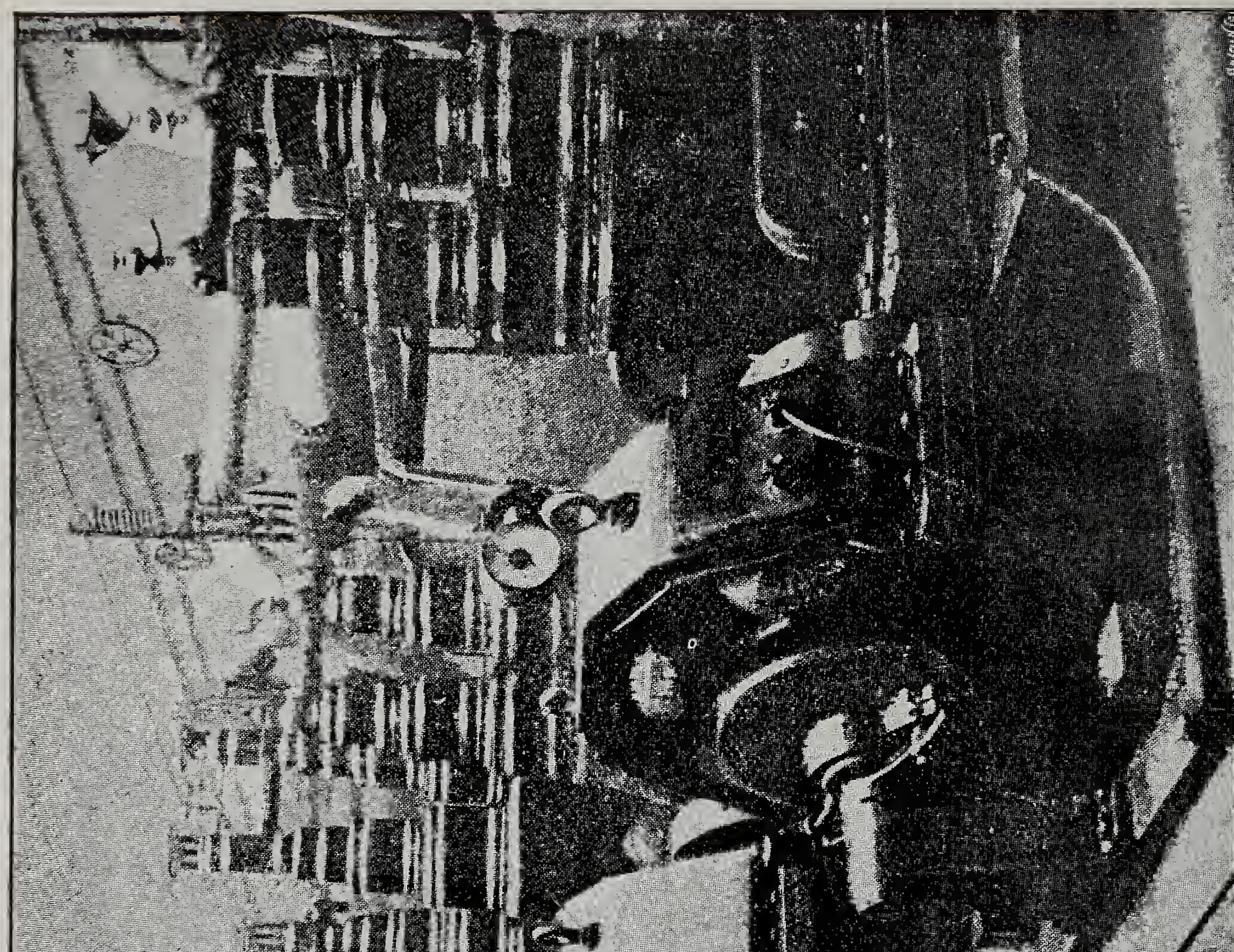
IN the July number of this magazine it was stated that Mr. E. H. Johnson was making the designs for a new combined electric-lighting plant. An experimental engine and dynamo has since been constructed, and is herewith illustrated. The engine, as will be wheels is 62 inches. The engraving shows two 50 kilowatt Lundell dynamos attached to the engine shaft, each of which has a capacity of 400 amperes at 125 volts. The plant will therefore furnish enough current for 1800 16-candle-power incandescent lamps. The



150 H. P. STRAIGHT-LINE ENGINE AND TWO 50 K. W. LUNDELL DYNAMOS.

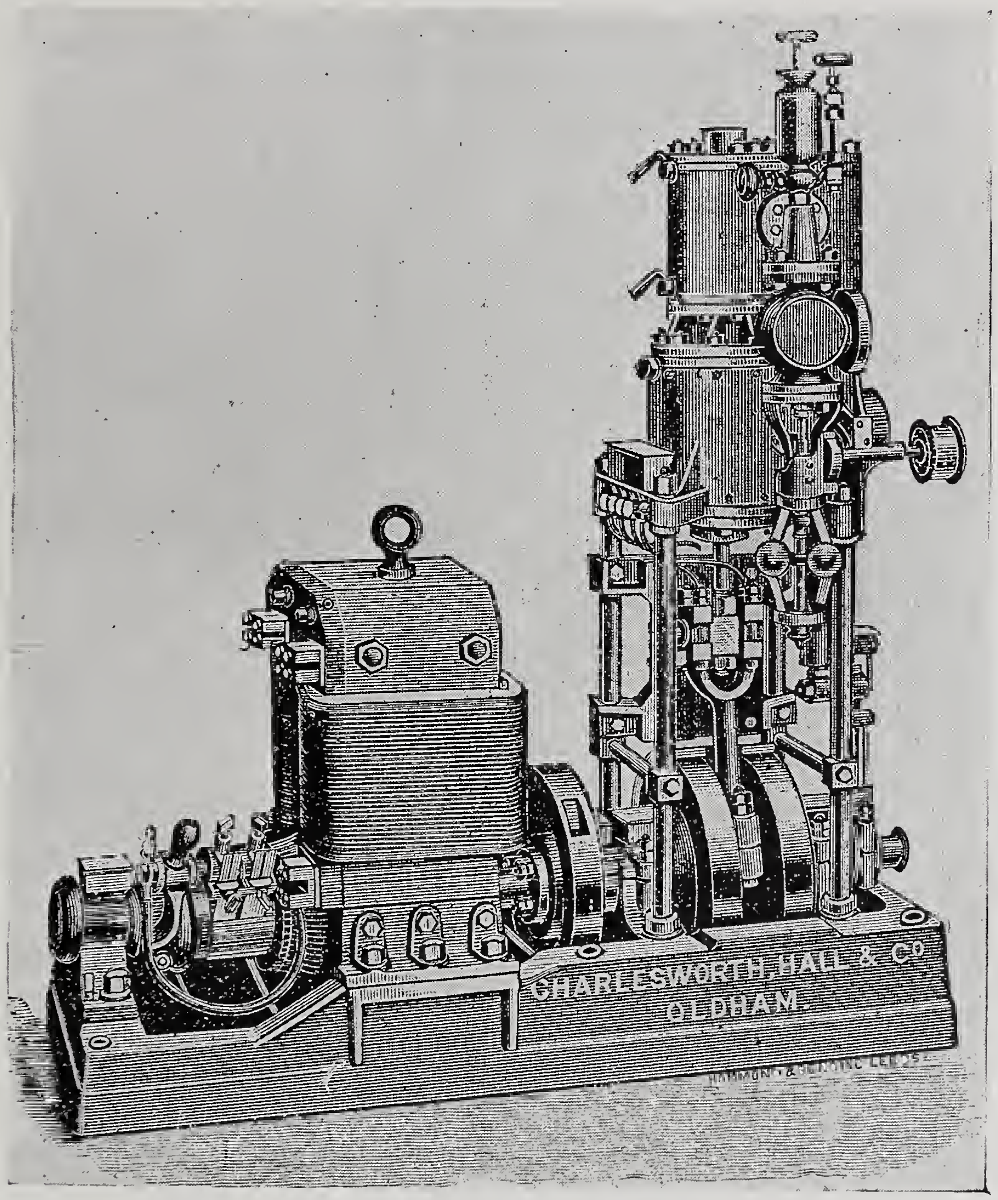
seen, is the usual "straight line" as constructed by Professor Sweet, but is provided with a special bedplate and special bearings. It will develop 150 horse-power, running at 220 revolutions per minute, with 120 pounds steam pressure. The diameter of the fly- total width of the armatures is 6⅛ inches, with an outside diameter of 51 inches. Although four brushes are shown in the engraving, yet the machines can be run with two brushes, as they are series wound.

It is proposed to build a vertical plant



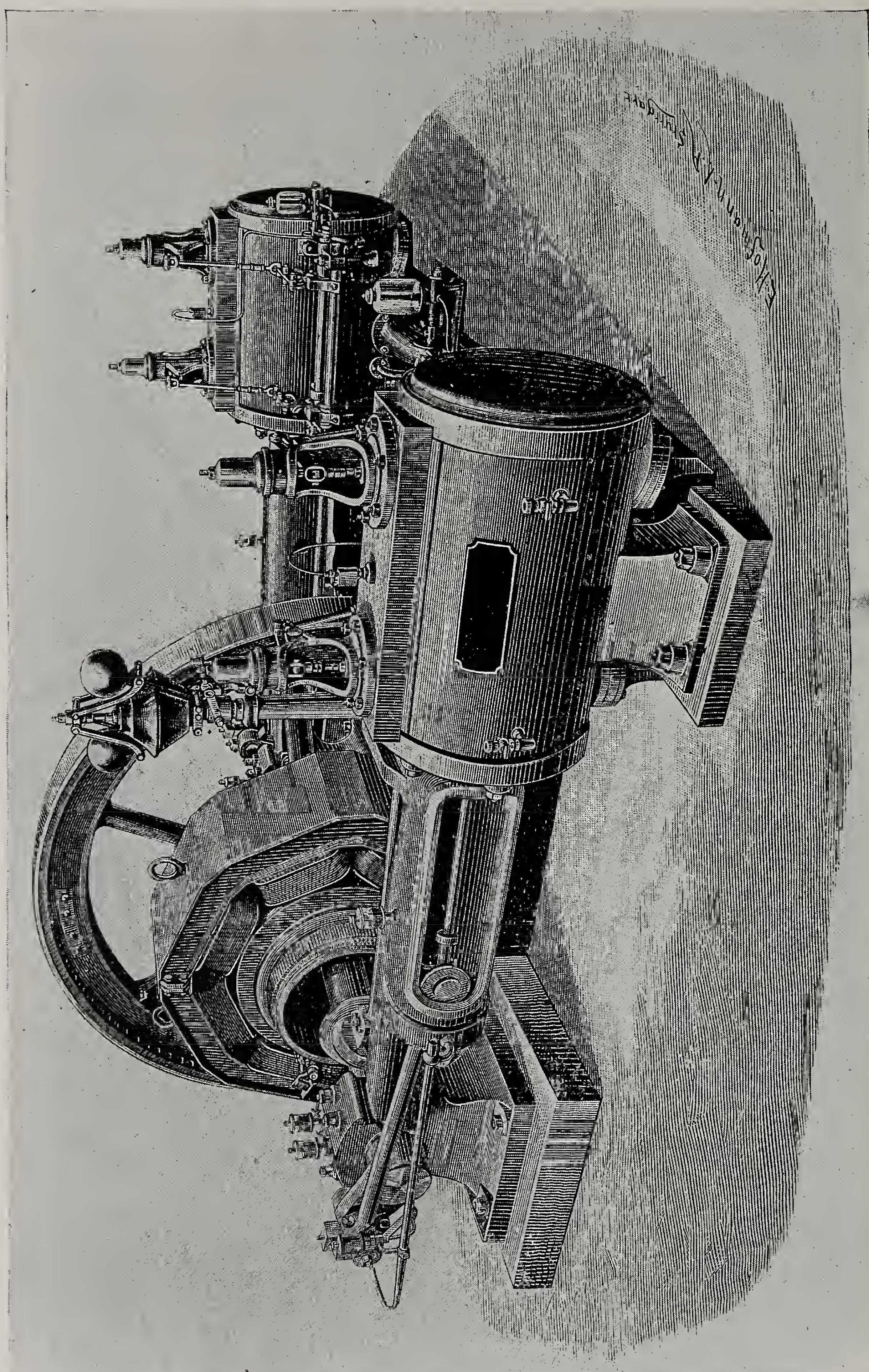
INTERIOR OF THE REGENT'S PARK STATION, LONDON.

of this general design for ship-lighting purposes. The engine shaft will hereafter be provided with an outboard thrust bearing, the desirability of which has been shown in the trials of this first engine. A shop is being constructed at Hartford, Conn., for the manufacture of these steam dynamos, although for the present the dynamos will be built separately for direct connection with any style of engine, in which case it is intended to use either a Brotherhood coupling or a standard so-called "Raffard" coupling, which is much used in France.



COMPOUND ENGINE AND DYNAMO, CONSTRUCTED BY CHARLESWORTH, HALL & CO., OLDHAM, ENGLAND.

Messrs. Willem, Smith & Co., of Slikkerveer, Holland, according to *Industries*, have recently supplied the combinations illustrated on another page for the Dutch colonial warships *Sumbana* and *Lombok*. The object aimed at in designing these generators was the production of a light but strong machine for running at low speeds. The dynamo has a large Gramme ring with internal stationary magnets. The output is 70 volts and 150 amperes at 190 revolutions per minute. The armature is 36 inches outside diameter, and 10 inches long, the iron being 2½ inches thick. The field magnet has four poles, and, as cross connections would be awkward in such a machine, four brushes are used to collect the current. The engine is of the ordinary type, with 6½-inch cylinders and 8-inch stroke, and is supplied with steam at 160 pounds per square inch. The dimensions of the plant are: Length, 7 feet 4 inches over all; height, 6 feet; breadth, 3 feet 4



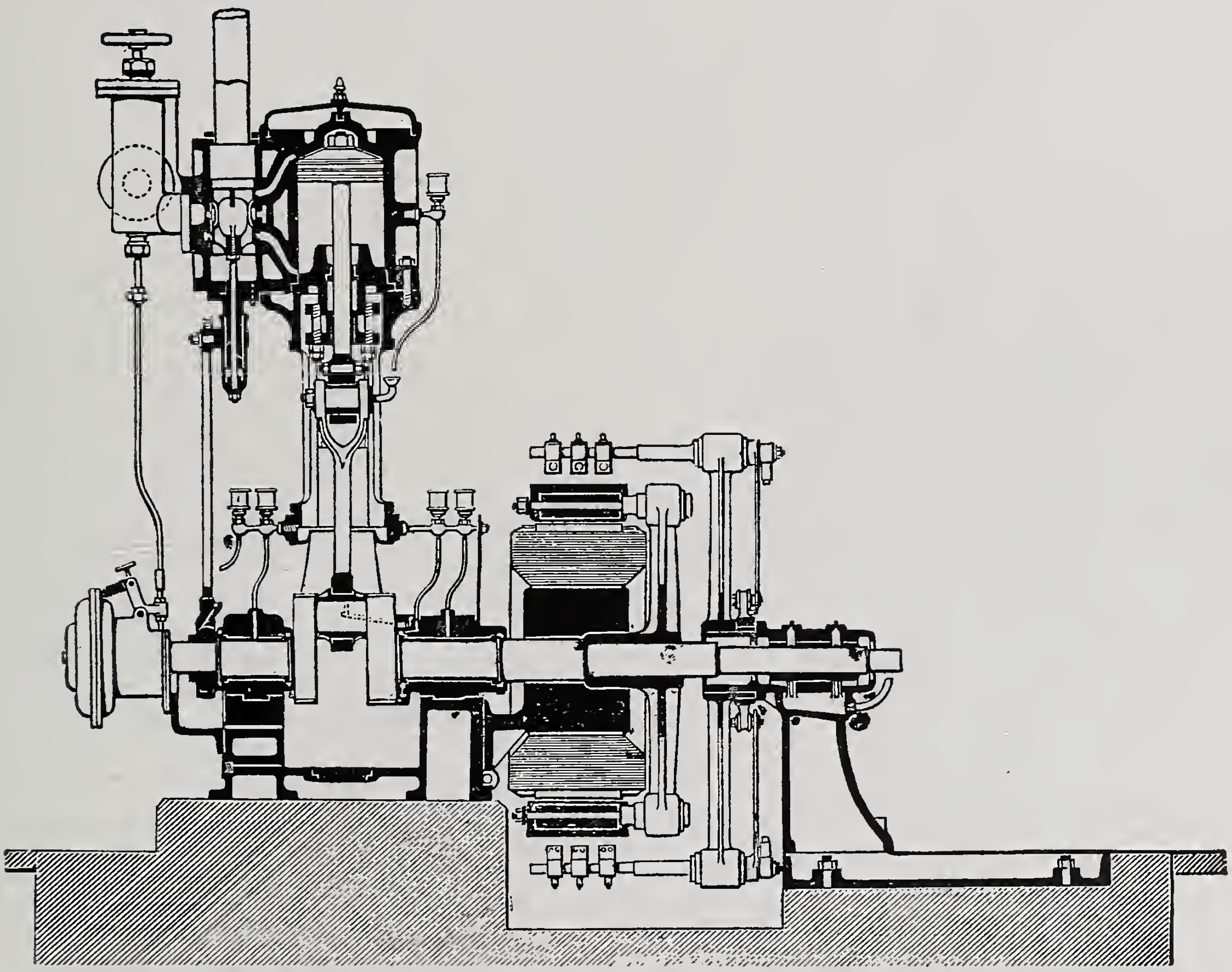
THE MASCHINENFABRIK, ESSLINGEN, EIGHT-POLE, 60 KILOWATT DYNAMO, COUPLED DIRECT TO A HORIZONTAL COMPOUND ENGINE.

inches. The total weight, including the wrought-iron bedplate, is 2½ tons.

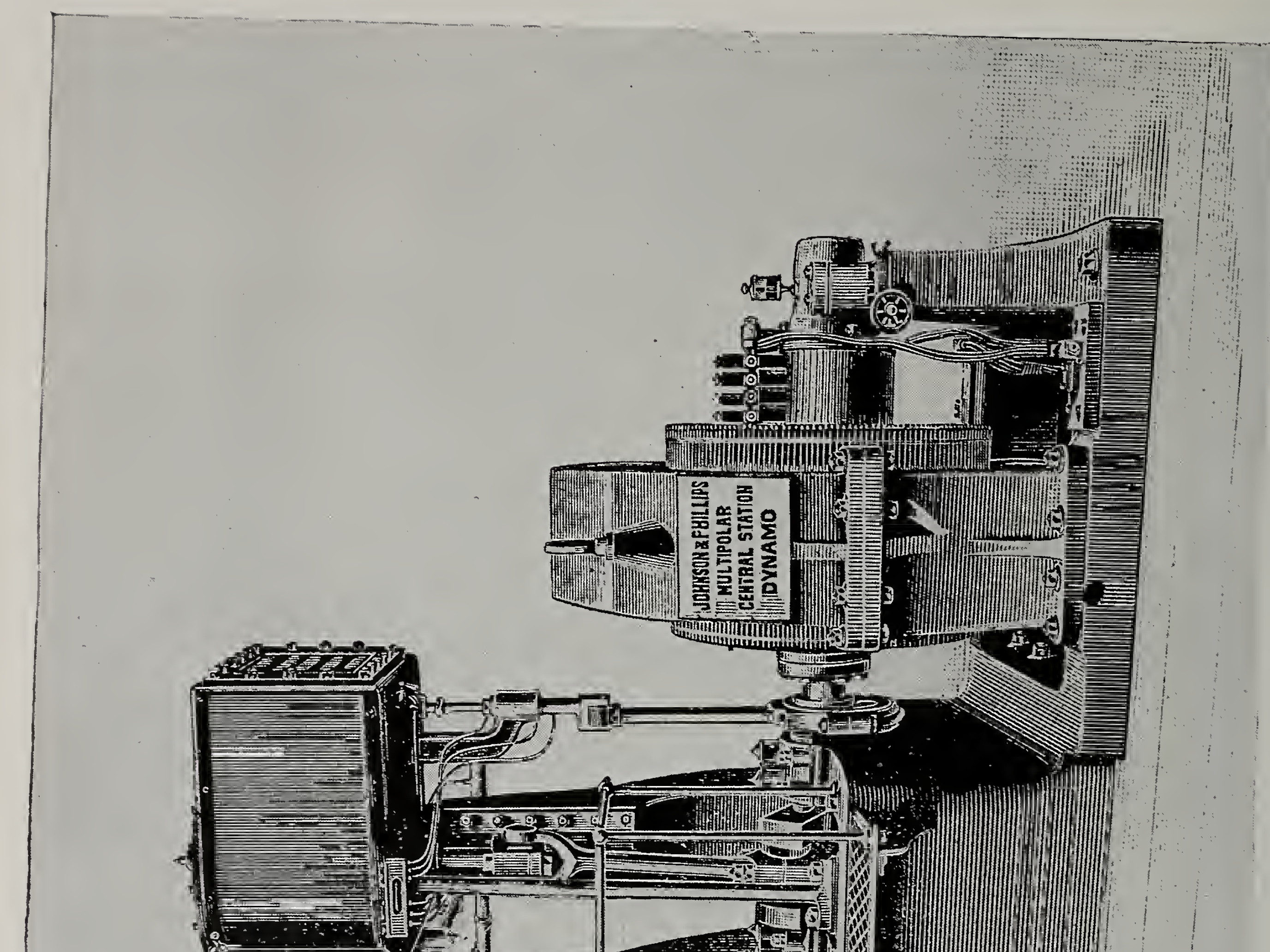
Upon another page is given a clear view of the interior of the Regent's Park station at London, taken from the *Electrical Review.* Referring to the arrangement of the generating plant, it can safely be said that as a model it occupies a high position. Willans triple-expansion engines are used at a steam pressure of 175 pounds. There are fixed in the station nine low-tension Kapp multipolar dynamos of 680 amperes each, working from 130 down to 100 volts. In addition there are two high-tension dynamos (coupled), intended to be used for street-lighting.

The Maschinenfabrik, Esslingen, exhibited an eight-pole 60 kilowatt dynamo at the Frankfort exhibition, for which the builders claimed not that it should do a large quantity of work for its weight, but should give the highest electrical return for the consumption of a given quantity of fuel. This machine, as shown in the cut, is coupled direct to a horizontal compound engine, and gives at a speed of 100 revolutions per minute a current of 124 amperes, at a difference of potential of 480 volts. The engine cylinders are 12¾ and 19¾ inches diameter respectively, and the stroke is 23½ inches. The working pressure is 120 pounds, and the steam is admitted by double-beat valves in conjunction with trip gear, the point of cut-off being controlled by the governor.

Messrs. Pokorny & Wittekind, of Germany, constructed the four-pole 15 kilowatt machine shown herewith in section. This machine is direct coupled, and, running at a speed of 400 revolutions per minute, it gives 246 amperes at 65 volts pressure. The armature core is constructed of thin iron plates, insulated from each other in the usual way, and having two stronger rings on the outside, to clamp the whole together and give it the necessary stability. The armature winding is of copper bars, with *papier-maché* between the adjacent convolutions, and the joints



SECTIONAL VIEW OF MACHINE, CONSTRUCTED BY MESSRS. POKORNY & WITTEKIND, GERMANY.

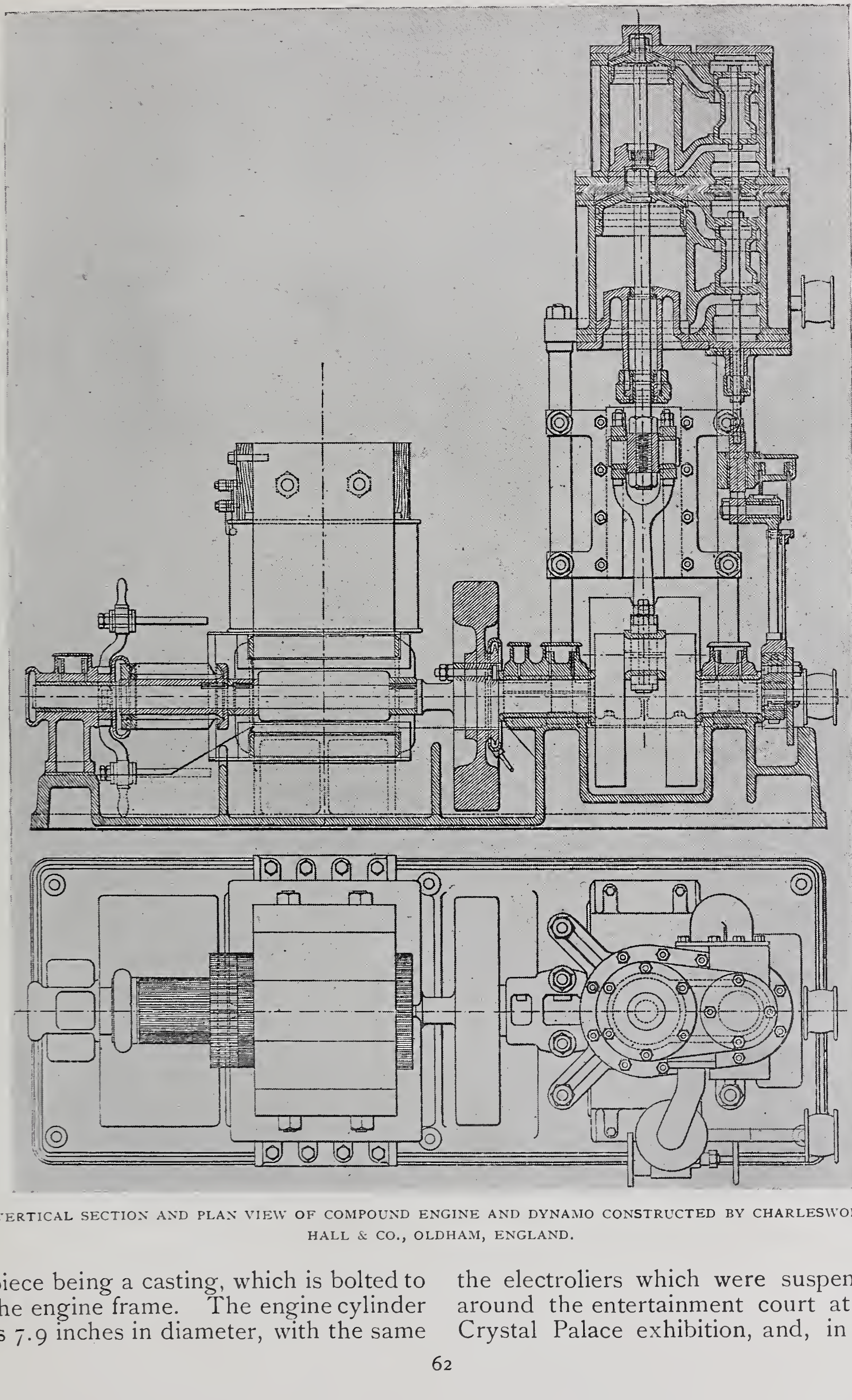


ENGINE AND DYNAMO, BUILT BY DAVEY, PAXMAN & CO., COLCHESTER, ENGLAND.

are dovetailed and soldered. The four radial magnets, with their pole shoes, are of wrought iron, the central yoke

length of stroke of piston, the working pressure being 120 pounds.

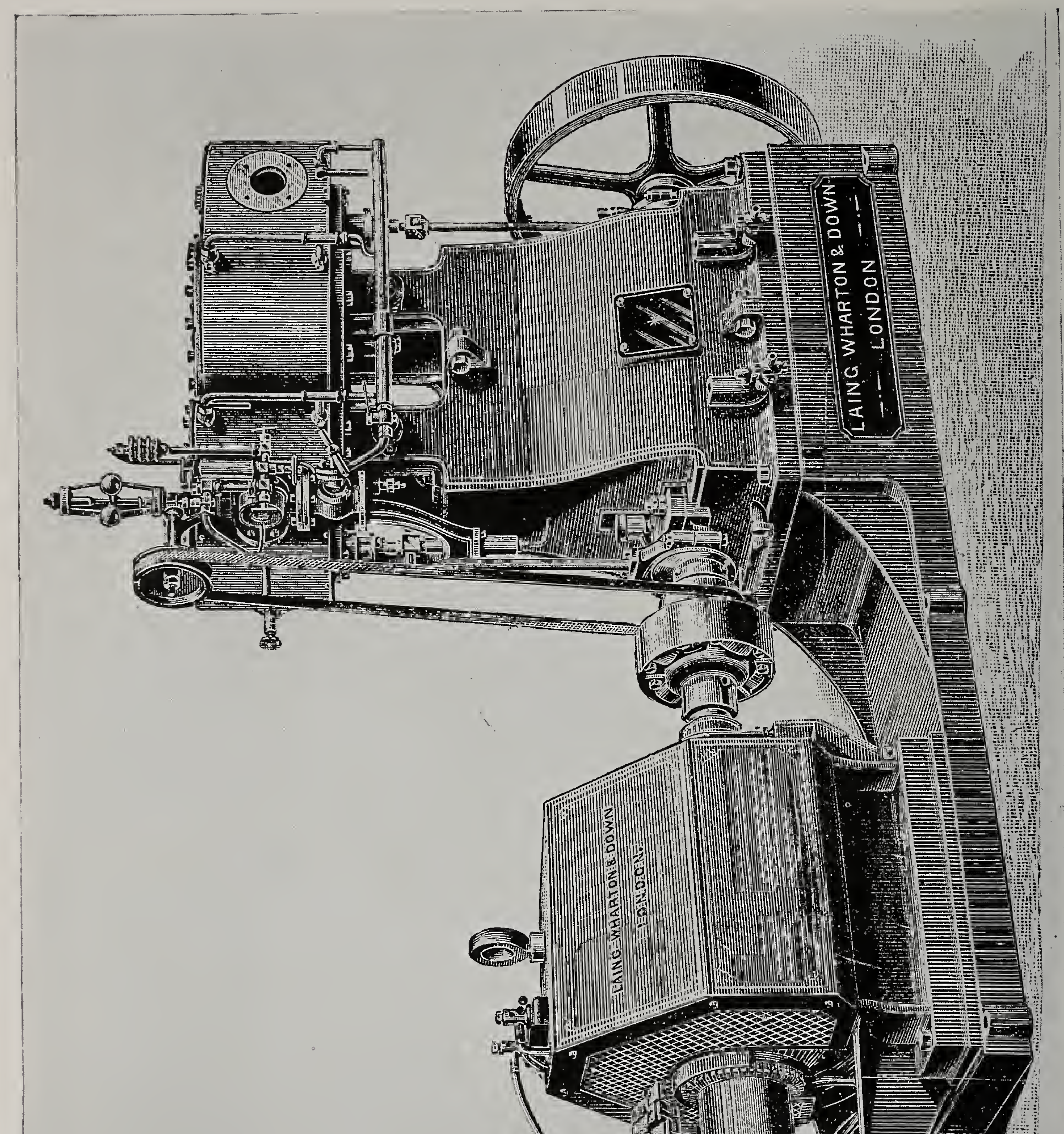
The work of lighting the whole of



VERTICAL SECTION AND PLAN VIEW OF COMPOUND ENGINE AND DYNAMO CONSTRUCTED BY CHARLESWORTH, HALL & CO., OLDHAM, ENGLAND.

piece being a casting, which is bolted to the engine frame. The engine cylinder is 7.9 inches in diameter, with the same

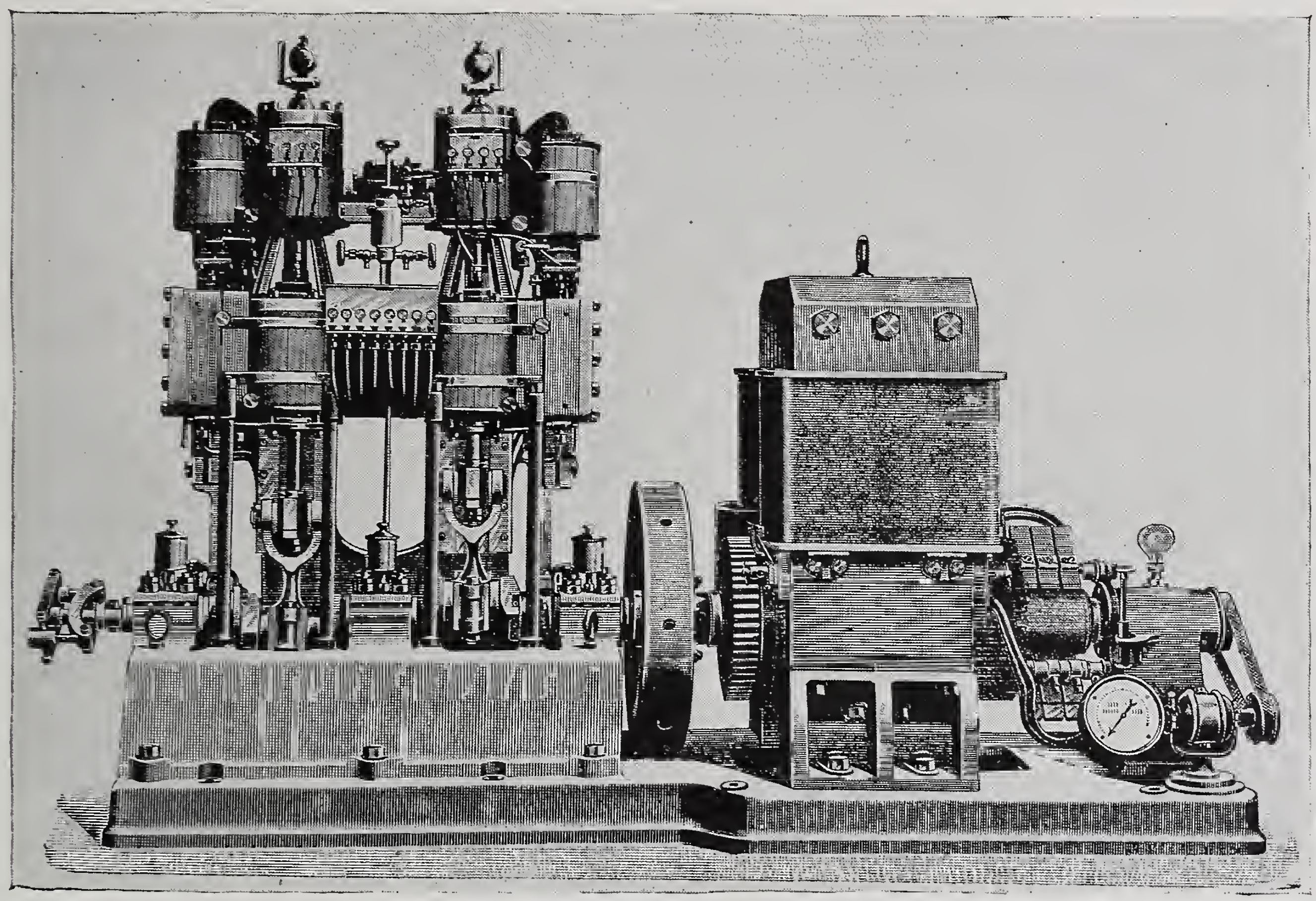
the electroliers which were suspended around the entertainment court at the Crystal Palace exhibition, and, in ad-



ELECTRIC-LIGHTING PLANT, BUILT BY MESSRS. LAING, WHARTON DOWN, LONDON.

dition, the illumination of the fountain in the central transept, was performed by an electric-lighting plant built by Messrs. Laing, Wharton & Down, of London. This plant, an engraving of which is shown on another page, consisted of a Robey vertical inverted compound engine, with Pickering governor and "special" compound-wound dynamo, coupled direct. The engine was designed to work with a pressure of from 80 to 100 pounds per square inch, at a speed of 300 revolutions per minute. Steadiness of running is easily attained by the use of such governors as the Pickering, which acts with immediate effect at every alteration of load, and, combined with efficient compounding in the dynamo, renders the light absolutely steady. The dynamo is intended to supply the current for 400 16-candle-power lamps of 100 volts. The builders claim for these machines that they are free from exterior magnetism, and that they therefore cannot affect watches or variations of compasses.

The aim in this series of papers has been to show what has been done, on both sides of the Atlantic, in the manufacture of engines for direct connection to electrical generators.

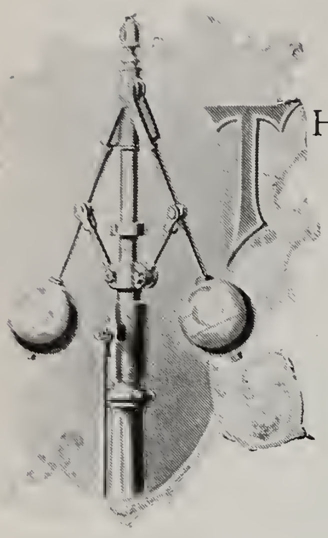


AN EXCELLENT COMBINATION.

The direct, coupled type of steam generator stands to-day the best and simplest device by which the heat of the steam can be turned into current on a wire. The American engineers are now fully aware of the value and economy of the combined plant, and rapid progress in this direction will undoubtedly be made during the next few years.

THE GOVERNING OF STEAM ENGINES.*

By William S. Aldrich, M. E.



THE matter of governing steam engines for uniform speed and economy in the use of steam becomes more difficult as the size of engine is increased. Especially exacting are these requirements in the electrical service, whether for light, power, or railway work, with the extended use of marine engines of the vertical inverted multiple-expansion type. These are directly coupled (or, at most, directly belted) to large multipolar dynamos,—two or more for each engine unit. The rotative speeds are consequently much higher than in the same type of engines at sea, and the boiler pressures are also greater; for the concentration of great engine power in a limited space becomes a serious question in the construction of large municipal electrical-supply plants, in or near the center of the area of distribution. This, with the demand for economy, has led to the adoption of the marine engine in central-station work.

The inherent difficulties of governing steam engines cannot be overcome. The only control of the steam supply is during admission, whether by controlling the pressure or the point of cut-off, or both. The variable driving effort on the piston due to expansive working, the variable effect of the inertia of the reciprocating parts, and the variable crank efforts can only be more or less met by the steadying action of a well-designed fly-wheel. The nature of the problem presented—in view, especially, of marine engines in central stations—may be outlined as follows:

1. The speed regulation to be as nearly perfect as the operation of the governing forces and of the regulating mechanism will permit.

2. The steam supply to be as directly proportioned to the external load as the mechanism of the steam engine will allow, by varying the main effective pressure on the piston.

3. Automatic regulation of the point of cut-off alone, or of all the events of the steam stroke if desired.

4. The valve, valve mechanism, and governor mechanism to be as free as possible of any needless frictional resistance, requiring a minimum power to alter their motions in sense, direction, or magnitude.

5. The governing forces to be brought into operation upon any change of speed or of external load, or of both at the same time, by compounding the centrifugal and the load governing principles.

6. The centrifugal governing forces to operate on the valve mechanism at a minimum required variation of speed.

7. The load or dynamometric governing forces to be indirectly applied, and not through the intervention of mechanism by and through which the power is transmitted from the engine to the dynamo.

8. The instantaneous variations of the external load to be as immediately and positively felt at the valve as the load governing mechanism will permit.

9. The variations, through any cause, of the driving effort on the piston and internal friction of the engine, as distinct from the external load variations, to be controlled by effective and sensitive centrifugal governing.

10. The compounding of the centrifugal and the load governing forces to be effected in such a way that they shall operate upon the valve independently of each other, or more or less dependently.

In discussing Mr. F. H. Ball's paper before this society on the new principle

* Paper read before American Society of Mechanical Engineers.

in steam-engine governing, Mr. W. C. Kerr† states the primary requirements of an engine governor to be: 1. A reasonably small variation in speed, light or loaded; 2. A very small acceleration for an instant, following a change of load; and, where the most delicate regulation is required, this instantaneous acceleration is of much greater consequence than the difference in revolutions between light and loaded conditions.

A compound automatic cut-off valve mechanism, operated by centrifugal and load governing forces, presents a somewhat satisfactory solution of almost all of these questions. Consider the case of a single valve for a single-cylinder engine. The two governing forces may be introduced by making the valve of the piston type, and giving it a variable movement of reciprocation, with a variable movement of rotation or of oscillation, the movements being independent of each other. The valve friction will be reduced to a minimum by combining reciprocation with rotation. The centrifugal governing forces control the variable reciprocation; the load governing forces the variable rotary movement, or *vice versa*. An electro-magnetic mechanism under control of the turning moment of the dynamo, or of its external electrical circuit, introduces the load or dynamometric principle. This electro-magnetic control of the point of cut-off not only possesses great facility of application, but differs from all other applications of the dynamometric principle in not requiring intermediate transmissive mechanism, with gear-wheel or pulley trains, nor weights, springs, or belt-tension devices of ordinary transmission dynamometers. It also acts instantaneously upon any change of load on the dynamo circuit; and, it is not possible to anticipate further any load changes, because the slightest change of load is instantly felt at the valve, through the electro-magnetic mechanism controlling one of its movements.

An analysis of some of the combinations more or less desirable as to the steam supply gives to the reciprocating movement the main control, and to the rotary movement the auxiliary or independent cut-off, or *vice versa*. Both rotary and reciprocating movements may be operated independently or in conjunction with each other. In a single rotary-piston valve all the points of the steam stroke are under control. Arranged for the Corliss type, the rotary-piston valves would be used at each end of the cylinder to control the admission and cut-off, while release and compression are fixed for the best normal working conditions. In multiple-expansion engines each cylinder is fitted with a rotary-piston valve, though in some cases load governing forces may alone be used to control the steam supply for the low-pressure cylinder.

The valve of the piston type, placed vertically in the vertical inverted marine engines at the central station, reduces valve friction to a minimum when it is rotated and reciprocated each to a continuously varying extent. Variable steam admission and cut-off is effected by helical or other curved ports in the piston valve and its seat. The two elements of the helical port may be designed independently or otherwise, according to the conditions under which the valve is to operate. The valve will thus have large port opening when most needed, and quick cutting-off qualities.

A compound movement of the stem of the rotary-piston valve may be accomplished, for instance, by giving the centrifugal shaft governor control of the reciprocation, and the electro-magnetic mechanism control of the rotary movement by and through a turning sleeve (as a guide block) fitted over a squared portion of the reciprocating valve stem. Many other simple devices to get this compound variable helical motion of the valve will suggest themselves as circumstances arise.

The mechanism for both variable reciprocation and rotation may be any one of the many well-known forms, such as the pendulum and the compound eccentric for reciprocation, and quick-return-motion mechanism of the Whitworth or other types for rotation. Or mechanical combinations may be replaced by their kine-

*Trans. Amer. Soc. Mech. Eng., Vol. IX., 1887–'88, pp. 315, 316.

matical equivalents in the form of electro-magnetic mechanisms. The peculiar advantage of the latter in this case is that the variable electro-magnetic forces under control of the dynamo load may be applied directly to the valve stem at the most convenient point, and without any reducing or other intermediate mechanism of a mechanical nature. This will also reduce the friction in the governing mechanism.

The electro-magnetic mechanism employed to control the valve movement more or less in proportion to the external load may be of several typical forms, utilizing different principles in the operation of electro-magnetic machinery.† The solenoid mechanism, for reciprocating rectilinear or curvilinear movement, having its coils connected in electrical circuit with the dynamo, and its iron core plunger connected to the valve mechanism ; the armature mechanism, for partial or complete rotatory movement, whose small shaft is the valve stem, which is thus brought under electrical control of the dynamo current ; and an armature mechanism utilizing a proportional part of the turning moment (torque) of the main dynamo which is directly coupled to the engine (or may be otherwise driven),—these are some of the combinations desirable. In fact, these are sliding or turning pairs, under direct electro-magnetic control of the dynamo current, which may be used with the complementary movement from the centrifugal governor mechanism to produce the resultant variable helical movement of the rotary-piston valve, and so control the steam supply.

The fundamental principle of a rotary-piston valve makes it possible to apply it to other cases than that here considered especially. It admits of controlling the point of cut-off by hand, as in the Stephenson and other link motions, with reversibility, so adapting it to the locomotive and marine service where no special uniformity of speed is called for. The reciprocations may be made by a fixed eccentric, as in the "Trenton" steam engine of the Phœnix Iron Company ; and here the partial rotation is controlled by the tripping mechanism and dash-pot accompaniment of a fly-ball governor like the Corliss type. A hand-wheel on the valve stem, or connected by suitable mechanism, would give absolute control of the steam supply and point of cut-off in locomotive and marine engines whose eccentrics are fixed (of constant eccentricity).

On the other hand, the rotary movement may be made the chief element of the valve motion, and the reciprocation controlled by hand by an auxiliary device. One rotary-piston valve may thus perform all the functions of an independent cut-off, as in the Buckeye and Meyer types, whether reciprocation or rotation be the chief element of its motion. In the latter, too, the rotary movement may be a partial or complete rotation, and either of these uniform or variable.

The rotary-piston valve, with its variable compound helical motion, possesses all the advantages of a slide valve and a piston valve, and the inherent disadvantages of neither. There is no scoring or grooving of the valve face or its seat, hence minimum liability to leakage and a maximum duration of normal working conditions. The structural advantages of piston valves are all maintained. By giving a rotary motion to a piston valve, or a sliding motion to a rotary valve, as is here done, the governing forces are a minimum to effect any change in either motion of the valve, for the angular movement is more easily varied than it would be with no sliding, and the travel of the valve is more easily changed than with no rotation. These features make it very easy to control one or the other movements by hand in locomotive and marine engines, or by sensitive governing mechanism for central-station engines ; and in the latter case this becomes a marked advantage, as it allows of dynamometric governing by delicate adjustments of the electro-magnetic mechanism to suit the external load conditions.

The advantages of governing central-station and other engines in the electrical service by compounding the centrifugal

† See "Notes on Electro-Magnetic Machinery," *Journal Franklin Institute*, February and March, 1892.

and the load governing forces by a rotary-piston valve may be thus summed up :

1. Best combination of conditions for uniform speed under no load or extreme variations of load, and steam pressure constant or slightly variable.

2. Steam supply as directly and instantaneously proportioned to the external load as it is possible to make it by electro-magnetically controlling the point of cut-off.

3. Valve friction reduced to a minimum.

4. Load governing forces capable of the most sensitive and delicate adjustment by electrical means.

5. Independent governing against variations in the external load compared with variations of driving effort and of the internal load of the engine.

6. Each governing principle regulates that which the other cannot, and without interference.

7. Rotary-piston valve with helical ports gives quick and sharp cut-off, with increased port area.

8. Failure of either governing device permits of the engine running temporarily under control of the other.

9. Dynamometric governing of a multiple-expansion engine driving several dynamos, any one of which may be thrown on or off at any time.

DENSITY OF WATER AT DIFFERENT TEMPERATURES.*

By A. F. Nagle, Member Am. Soc. Mech. Eng.

THE writer has frequent occasion to use a table of "weight of water at different temperatures," and he is somewhat uncertain as to the most reliable table published. There does not appear to be any unanimity among authors as to the density of water at *any* temperature. One would suppose that at its maximum density, and at the boiling point, there would be perfect agreement, but there is not.

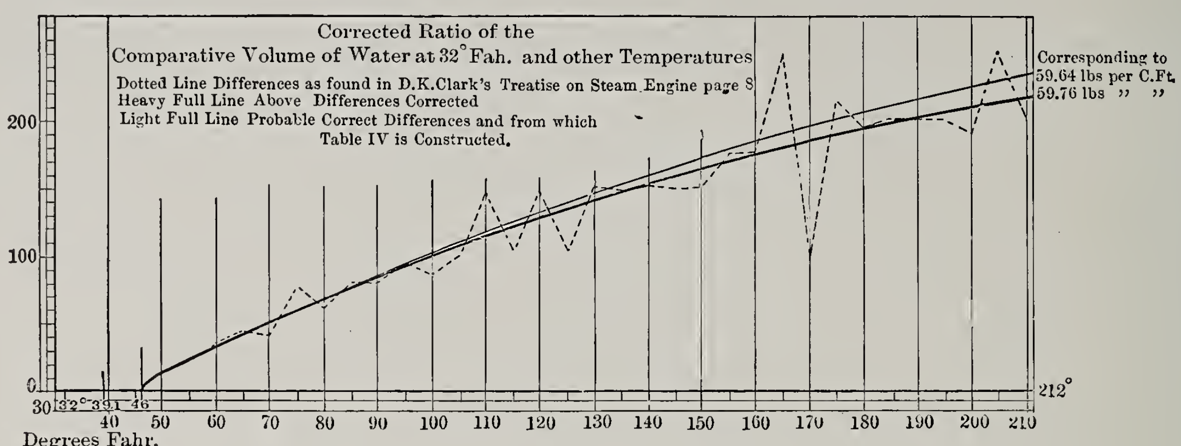


FIG. I.

J. W. Nystrom, "Steam Engineering," gives a table computed for every degree to four places of decimals, from the original experiments of Kopp, beginning with its maximum density at 40° as 62.3880 lbs. c.f., and ending at 212° with 59.8376 lbs. c.f.

"Steam," published by the Babcock & Wilcox Co., gives a table for nearly every degree, beginning with its maximum density at 39.1° as 62.425 lbs. c.f., and ending at 212° with 59.760 lbs. c.f.

This table is evidently computed from Rankine's approximate formula as given by Clark.

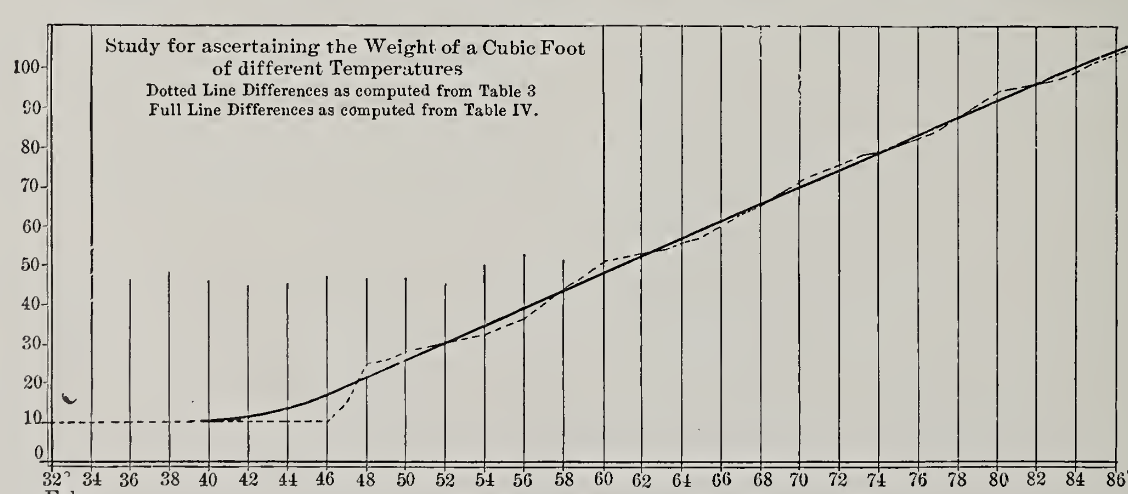


FIG. 2.

Mr. Clark, "Steam Engine," gives a table for every five degrees computed from Rankine's formula, giving the same results as above quoted from "Steam," but not worked out with as much care.

Thurston, "Steam Engine and Boiler Trials," does not mention his authority,

* Paper read before the American Society of Mechanical Engineers.

but gives a table for every 10° with its maximum density at 39.2° as 62.425 lbs. c.f., and at 212° as 59.707 lbs. c.f.

The British imperial standard gallon is based upon 10 lbs. of pure water at 62° Fah., 277.274 cubic inches for its volume. A simple calculation will give the weight of a cubic foot at this temperature as 62.3210 lbs., and Mr. Clark gives it as 62.3550 lbs.

Grouping these figures in a table enables us to compare them the better.

Mr. Nystrom says: "The most reliable experiments made on this subject are probably those of Kopp, by which the greatest density of water is indicated to be between 39° and 40°, or nearer

WEIGHT OF A CUBIC FOOT OF WATER AS GIVEN BY DIFFERENT AUTHORITIES.

Tem. Fah.	Clark.	Nys-trom.	Thurs-ton.	British Gallon.	Amer. Gallon.
39.1	62 425	62.3879	62.4250	‡62.3880	‡62.3791
40.	62 425	62.3880	62.4230	....	
62.	62.355	62.3211	....	62.3210	
212	59.760	59.8376	59.7070		
"	By measurement 59.640		*59.8445		
"			†59.8330		

* Corrected (?) † Kopp, corrected by Porter.
‡ Calculated.

39°. But, however accurate these experiments might have been made, it is impossible without the aid of mathematics to determine correctly the temperature of the greatest density, because the curve tangents the abscissa at that point.

"The writer treated Kopp's experiments with very careful mathematical and graphical analysis, the result of which located the greatest density of water at 40°." (Now, however, generally accepted as being at 39.1°.)

"The formula for volume of water deduced from Kopp's experiments is:

$$V = \frac{(t-40)^2}{1400\,t + 398{,}500} \quad . \quad . \quad (1)$$

"The volume deduced from the same experiments, but with the assertion that the greatest density of water is at 39°, will be:

$$V = \frac{(t-39)^2}{1400\,t + 405{,}400} \quad . \quad . \quad (2)$$

"The formula (1) is the most correct." (?)

Thurston does not mention his authority. It is evident it is not Kopp, nor Kopp corrected by Porter, both tables being given on same page with his own, for it is not in agreement with either.

The maximum density Thurston gives at 39.1° as 62.425 lbs., but at the boiling point, while he gives the same comparative volume as Kopp, namely, 1.04312, yet the rate deduced from this

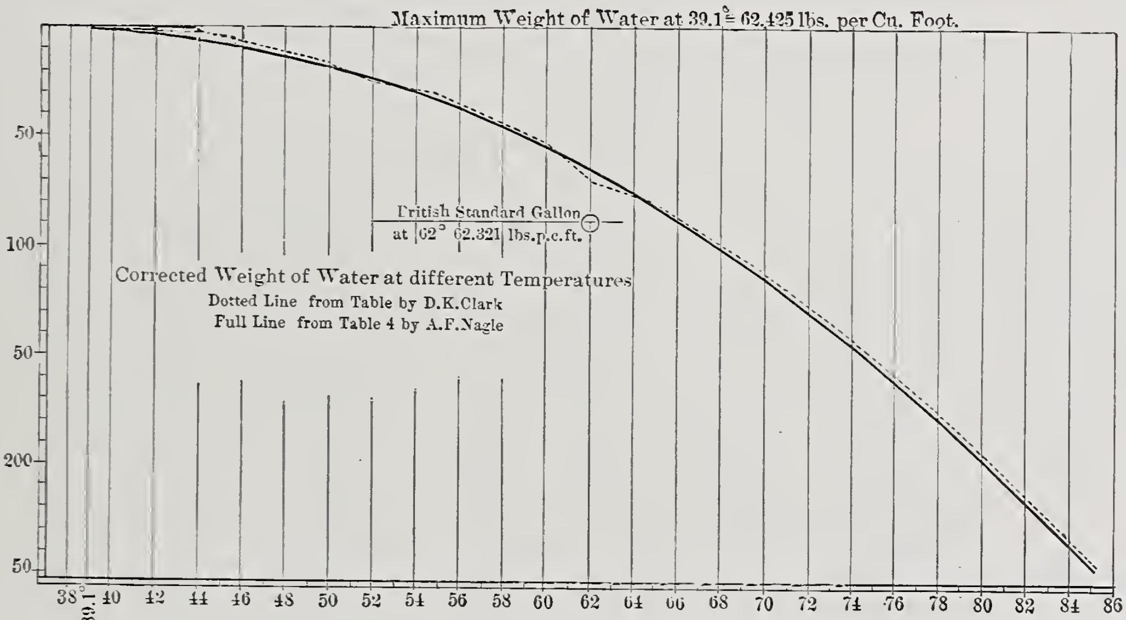


FIG. 3.

ratio of volumes is given as 59.707 lbs. There is either an error in the comparative volumes or in the weight, for they do not check up correctly, because,

$$\frac{62.425}{1.04312} = 59.8445 \text{ lbs.}$$

instead of 59.707 lbs.

If we use Porter's corrected figure, we have:

$$\frac{62.425}{1.04332} = 59.8330 \text{ lbs.}$$

Mr. Clark says: "The results given by this rule are very nearly exact for the lower temperatures, but for the higher temperatures they are too great. For 212° Fah. the density of water by the rule is 59.76 lbs., but it is actually only 59.64 lbs."

I presume it is safe to accept Mr. Clark's figure for this corrected weight by direct measurement at 212°, although no other author quoted gives it. One would suppose that the weight of a cubic foot for 62°, from which the imperial gallon is established, would be absolutely correct, but I believe this standard was adopted when it was *supposed that* to be the relation of volume to weight; but as it is not, the volume of 277.274 cubic inches remains to be the correct standard, and the weight of water may as well be left out of the discussion.

TABLE I.

Temperature. Fahr.	Comparative Volume with water at 32 degrees.	1st Differences.	2d Differences.	Temperature. Fahr.	Comparative Volume with water at 32 degrees.	1st Differences.	2d Differences.
32	1.00000	....	....	120	1.01139	150	50
35	0.99993	7	....	125	1.01239	100	−50
39.1	0.99989	4	−3	130	1.01390	151	51
40.	0.99989	0	−4	135	1.01539	149	−2
45	0.99993	4	4	140	1.01690	151	2
46	1 00000	7	3	145	1.01839	149	−2
50	1.00015	15	8	150	1.01989	150	1
52.3	1.00029	....	....	155	1.02164	175	25
55	1 00038	23	8	160	1.02340	176	1
60	1.00074	36	13	165	1.02589	249	73
62	1.00101	....	—	170	1.02690	101	−148
65	1.00119	45	9	175	1.02906	216	115
.70	1.00160	41	−4	180	1.03100	194	−22
75	1.00239	79	38	185	1.03300	200	6
80	1.00299	60	−19	190	1.03500	200	0
85	1.00379	80	20	195	1.03700	200	0
90	1.00459	80	0	200	1.03889	189	−11
95	1.00554	95	15	205	1.04140	251	62
100	1.00639	85	−10	210	1.04340	200	−51
105	1.00739	100	15	212	1.04440	100	
110	1.00889	150	50			——	
115	1.00989	100	−50			4440	

Mr. Clark does not say upon whose experimental data Professor Rankine's formula is based. I suspect it is Kopp.

Rankine's formula is as follows:

$$D_1 \textit{ nearly} = \frac{2\,D_0}{\dfrac{t+461}{500} + \dfrac{500}{t+461}}$$

at which $D_0 = 62.425$ lbs. per cubic foot, the maximum density of water.

And $D_1 =$ its density at a given temperature, t, Fah.

So great, however, is my confidence in Mr. Clark's accuracy of statement, that I will adopt his weights at the maximum density of water at 39.1° as 62.425

TABLE 2.

Temperature. Fahr.	Comparative Volume with water at 32 degrees.	1st Differences.	2d Differences.	Temperature. Fahr.	Comparative Volume with water at 32 degrees.	1st Differences.	2d Differences.
32	1.00000	....	....	125	1.01253	134	6
35	0.99993	....	....	130	1.01393	140	6
39.1	0.99989	....	....	135	1.01539	146	6
40.	0.99989	....	....	140	1.01691	152	6
45	0.99993	....	....	145	1.01849	158	6
46	1.00000	....	....	150	1.02013	164	6
50	1.00015	15	....	155	1.02182	169	5
52.3	1.00029	....	....	160	1.02356	174	5
55	1.00040	25	10	165	1.02535	179	5
60	1.00074	34	9	170	1.02719	184	5
62	1.00101	....	....	175	1.02908	189	5
65	1.00117	43	9	180	1.03102	194	5
70	1.00169	52	9	185	1.03300	198	4
75	1.00229	60	8	190	1.03502	202	4
80	1.00297	68	8	195	1.03708	206	4
85	1.00373	76	8	200	1.03918	210	4
90	1.00457	84	8	205	1.04132	214	4
95	1.00549	92	8	210	1.04350	218	4
100	1.00649	100	8			——	
105	1.00756	107	7	212	1.04440	4350	
110	1.00870	114	7			90	
115	1.00991	121	7			——	
120	1.01119	128	7			4440	

TABLE 3.

Temperatures. Fahr.	Comparative volume, with water at 32°.	1st Differences.	2d Differences.	Temperatures. Fahr.	Comparative volume, with water at 32°.	1st Differences.	2d Differences.
32	1.00000	....	....	125	1.01294	139	7
35	0.99993	−7	....	130	1.01440	146	7
39.1	0.99989	−4	....	135	1.01593	153	7
40	0.99989	0	....	140	1.01752	159	6
45	0.99993	4	....	145	1.01917	165	6
46	1.00000	7	....	150	1.02088	171	6
50	1.00015	15	....	155	1.02265	177	6
52.3	1.00029	....	....	160	1.02448	183	6
55	1.00040	25	10	165	1.02637	189	6
60	1.00075	35	10	170	1.02832	195	6
62	....	....	....	175	1.03032	200	5
65	1.00119	44	9	180	1.03237	205	5
70	1.00172	53	9	185	1.03447	210	5
75	1.00234	62	9	190	1.03662	215	5
80	1.00305	71	9	195	1.03881	219	4
85	1.00384	79	8	200	1.04105	224	5
90	1.00471	87	8	205	1 04333	228	4
95	1.00566	95	8	210	1.04565	232	4
100	1.00669	103	8	212	1.04659	——	
105	1.00780	111	8			4,565	
110	1.00898	118	7			94	
115	1.01023	125	7			——	
120	1.01155	132	7			4,659	

lbs. c.f., and at 212° as 59.640 lbs. c.f.

Having accepted these terminal points, how shall we obtain correct intermediate ones?

TABLE 4.

Temp. Fahr.	Comparative volume. Water at 39.1° = 1.	Differences.	Weight of one cubic ft. Pounds.	Differences.	Temp. Fahr.	Comparative volume. Water at 39.1° = 1.	Differences.	Weight of one cubic ft. Pounds.	Differences.
32	1.00014	.....	62.41623	......	93	1.00538	19	62.0908	117
33	1.00011	3	62.41790	16.7	94	1.00557	19	62.0789	119
34	1.00009	2	62.41935	14.5	95	1.00577	20	62.0668	121
35	1.00007	2	62.42063	12.8	96	1.00597	20	62.0545	123
36	1.00005	2	62.42181	11.8	97	1.00617	20	62.0420	125
37	1.00003	2	62.42292	11.1	98	1.00638	21	62.0293	127
38	1.00001	2	62.42398	10.6	99	1.00659	21	62.0164	129
39.1	1.00000	1	62.42500	10.2	100	1.00680	21	62.0033	131
40	1.00001	1	62.42398	10.2	101	1.00702	22	61.9900	133
41	1.00003	2	62.42292	10.6	102	1.00724	22	61.9765	135
42	1.00005	2	62.42181	11.1	103	1.00746	22	61.9629	136
43	1.00007	2	62.42063	11.8	104	1.00768	22	61.9491	138
44	1.00009	2	62.41935	12.8	105	1.00791	23	61.9351	140
45	1.00011	2	62.41790	14.5	106	1.00814	23	61.9210	141
46	1.00014	3	62.41623	16.7	107	1.00837	23	61.9067	143
47	1.00017	3	62.41434	18.9	108	1.00861	24	61.8922	145
48	1.00020	3	62.41223	21.1	109	1.00885	24	61.8775	147
49	1.00024	4	62.40990	23.3	110	1.00909	24	61.8626	149
50	1.00028	4	62.40735	25.5	111	1.00934	25	61.8475	151
51	1.00032	4	62.40458	27.7	112	1.00959	25	61.8323	152
52	1.00037	5	62.40159	29.9	113	1.00984	25	61.8170	153
52.3	1.00039	......	62.40063	......	114	1.01009	25	61.8015	155
53	1.00042	5	62.39838	32.1	115	1.01034	25	61.7859	156
54	1.00048	6	62.39495	34.3	116	1.01060	26	61.7701	158
55	1.00054	6	62.39130	36.5	117	1.01086	26	61.7541	160
56	1.00060	6	62.38743	38.7	118	1.01112	26	61.7380	161
57	1.00067	7	62.38334	40.9	119	1.01139	27	61.7217	163
58	1.00074	7	62.37903	43.1	120	1.01166	27	61.7053	164
59	1.00081	7	62.37450	45.3	121	1.01193	27	61.6887	166
60	1.00089	8	62.36975	47.5	122	1.01221	28	61.6719	168
61	1.00097	8	62.36478	49.7	123	1.01249	28	61.6549	170
62	1.00105	8	62.35959	51.9	124	1.01277	28	61.6378	171
63	1.00113	8	62.35418	54.1	125	1.01305	28	61.6206	172
64	1.00122	9	62.34855	56.3	126	1.01334	29	61.6032	174
65	1.00132	10	62.34270	58.5	127	1.01363	29	61.5856	176
66	1.00142	10	62.33663	60.7	128	1.01392	29	61.5679	177
67	1.00152	10	62.33034	62.9	129	1.01421	29	61.5500	179
68	1.00162	10	62.32383	65.1	130	1.01451	30	61.5320	180
69	1.00173	11	62.31710	67.3	131	1.01481	30	61.5138	182
70	1.00184	11	62.31015	69.5	132	1.01511	30	61.4954	184
71	1.00196	12	62.30298	71.7	133	1.01542	31	61.4768	186
72	1.00208	12	62.29559	73.9	134	1.01573	31	61.4581	187
73	1.00220	12	62.28798	76.1	135	1.01604	31	61.4392	189
74	1.00232	12	62.28015	78.3	136	1.01635	31	61.4202	190
75	1.00245	13	62.27210	80.5	137	1.01667	32	61.4011	191
76	1.00258	13	62.26380	83	138	1.01699	32	61.3819	192
77	1.00272	14	62.25525	85.5	139	1.01731	32	61.3626	193
78	1.00286	14	62.2465	87.5	140	1.01763	32	61.3432	194
79	1.00301	15	62.2375	90	141	1.01795	32	61.3237	195
80	1.00316	15	62.2283	92	142	1.01828	33	61.3040	197
81	1.00331	15	62.2189	94	143	1.01861	33	61.2841	199
82	1.00346	15	62.2093	96	144	1.01894	33	61.2641	200
83	1.00362	16	62.1995	98	145	1.01928	34	61.2440	201
84	1.00378	16	62.1894	100	146	1.01962	34	61.2238	202
85	1.00395	17	62.1792	102	147	1.01996	34	61.2034	204
86	1.00412	17	62.1688	104	148	1.02030	34	61.1829	205
87	1.00429	17	62.1583	105	149	1.02064	34	61.1622	207
88	1.00446	17	62.1475	108	150	1.02099	35	61 1413	209
89	1.00464	18	62.1365	110	151	1.02134	35	61.1203	210
90	1.00482	18	62.1253	112	152	1.02169	35	61.0992	211
91	1.00500	18	62.1140	113	153	1.02204	35	61.0780	212
92	1.00519	19	62.1025	115	154	1.02240	36	61.0568	212

Turning to Mr. Clark's table, the third column of which is reprinted in Table 1 of this paper, the first differences for the comparative volumes were taken and plotted as shown in dotted lines in Fig. 1. There are evidently errors in the computations of the table. I did not recompute the table, but constructed a smooth and graceful curve through the dotted lines, so that the total of the ordinates would be exactly the same as before. The heavy full line

shows this line, and the ordinates measured therefrom are given in Table 2. By taking second differences, the table was made somewhat more accurate than could be obtained from measurements.

This curve, and consequent table, could be received as perhaps a perfect exemplification of Rankine's formula, and yet it is possible, if the formula were worked out for every degree, that it would give as perfect a curve as I have laid out—but it is not *this* curve we want. Acting upon Mr. Clark's remark that the formula gives results comparative volumes given in Table 3, and a final Table 4 was worked up with great care for every degree from 32° to 212° for both weights and comparative volumes. First a table was constructed from Table 3 for every degree, with the purpose of keeping as closely as possible to the important figures given by Mr. Clark, and at one time I was disposed to leave the matter there, but plotting those results as shown in Fig. 2, it was so unsatisfactory that I decided to draw a new line of differences of weights. The dotted line shows the

TABLE 4 (CONTINUED).

Temp. Fahr.	Comparative volume. Water at 39.1° = 1.	Differences.	Weight of one cubic ft. Pounds.	Differences.	Temp. Fahr.	Comparative volume. Water at 39.1° = 1.	Differences.	Weight of one cubic ft. Pounds.	Differences.
155	1.02276	36	61.0355	213	184	1.03416	42	60.3626	246
156	1.02312	36	61.1040	215	185	1.03459	43	60.3379	247
157	1.02348	36	60.9923	217	186	1.03502	43	60.3131	248
158	1.02384	36	60.9705	218	187	1.03545	43	60.2881	250
159	1.02421	37	60.9486	219	188	1.03588	43	60.2630	251
160	1.02458	37	60.9266	220	189	1.03631	43	60.2379	251
161	1.02496	38	60.9045	221	190	1.03674	43	60.2128	251
162	1.02534	38	60.8822	223	191	1.03717	43	60.1876	252
163	1.02572	38	60.8597	225	192	1.03760	43	60.1624	252
164	1.02610	38	60.8370	227	193	1.03804	44	60.1370	254
165	1.02648	38	60.8140	229	194	1.03848	44	60.1115	255
166	1.02687	39	60.7912	229	195	1.03982	44	60.0860	255
167	1.02726	39	60.7682	230	196	1.03937	45	60.0604	256
168	1.02765	39	60.7451	231	197	1.03982	45	60.0346	258
169	1.02804	39	60.7220	231	198	1.04027	45	60.0087	259
170	1.02843	39	60.6988	232	199	1.04072	45	59.9823	259
171	1.02883	40	60.6755	233	200	1.04117	45	59.9569	259
172	1.02923	40	60.6520	235	201	1.04162	45	59.9309	260
173	1.02963	40	60.6284	236	202	1.04207	45	59.9049	260
174	1.03003	40	60.6048	236	203	1.04252	45	59.8788	261
175	1.03043	40	60.5812	236	204	1.04298	46	59.8525	263
176	1.03084	41	60.5574	238	205	1.04344	46	59.8261	264
177	1.03125	41	60.5334	240	206	1.04390	46	59.7997	264
178	1.03166	41	60.5093	241	207	1.04436	46	59.7733	264
179	1.03207	41	60.4851	242	208	1.04482	46	59.7467	266
180	1.03248	41	60.4608	243	209	1.04529	47	59.7201	266
181	1.03290	42	60.4363	245	210	1.04576	47	59.6935	266
182	1.03332	42	60.4117	245	211	1.04623	47	59.6668	267
183	1.03374	42	60.3872	246	212	1.04670	47	59.6400	268

almost in exact agreement with the facts at the lower temperatures, but too great at the higher, I drew a line of similar curvature as the former, tangent to it at the lower end, and elevated it at the upper end until the sum total of the ordinates, representing differences, gave the required amount necessary to make the weight of a cubic foot equal to 59.640 lbs., instead of 59.760 lbs.

The curve is shown in a light, full line, and the ordinates obtained are given in Table 3 for every 5°.

The weights were computed from the change made, and I believe it is justifiable. The decimals only are plotted. From these differences a new table was constructed and the comparative volumes computed with water at its maximum density, 39.1°, instead of at 32°.

In Fig. 3 the decreasing weight of a cubic foot is laid out, up to 86°, and what discrepancies exist between what Mr. Clark has given and what the writer gives I believe are in favor of the latter.

Agreements and Discrepancies. — I was very reluctant to change any figures at the lower temperatures which

might be considered as standards. At 39.1° I adopted 62.425 lbs., although Charles T. Porter gives it as 62.4245 lbs. Mr. Clark gives for 46° and 32° 62.4180 lbs. I could not get nearer to it than 62.41623 lbs.

A study of the diagrams will, I believe, justify this change.

I have given the weights below 39.1° in the same decreasing order and ratio as above 39.1°, thus reaching at 32° 62.4162 lbs., instead of 62.4180 lbs., as given by Mr. Clark. It was because I felt some uncertainty as to the absolute correctness of this figure that I thought it safer and better to base the comparative volumes upon its maximum density rather than at 32°.

At 52.3°, given by Mr. Clark as 62.400 lbs., the agreement is almost perfect, it being 62.40062 lbs.

At 62° occurs the greatest deviation, but a study of the diagram will justify the figure I have adopted, namely, 62.3596 lbs., instead of 62.3550 lbs.

At 65° there is almost perfect agreement.

After this my line gradually draws away from that obtained by Rankine's formulæ, so that the terminal at 212° may agree with what Mr. Clark says is the weight by actual measurement.

The American gallon has a volume of 231 cubic inches, and that is enough to define it. Mr. Trautwine, however, says it contains 8.33888 lbs. of pure water at its maximum density of 39.1°.

Upon that basis a cubic foot would weigh

$$\frac{8.33888 \times 1728}{231} = 62.3791 \text{ lb}$$

LEADING AMERICAN ENGINEERS.—C. J. H. WOODBURY.

By J. C. Bayles.

MR. C. J. H. WOODBURY, of Boston, whose portrait appears elsewhere in this issue, is one of the best known of the present generation of American engineers, and has won an honorable prominence by thorough and successful original work. He is a native of Lynn, Mass., and is a lineal descendant of John Woodbury, the surveyor of the Massachusetts Bay Colony, who came to America in 1624.

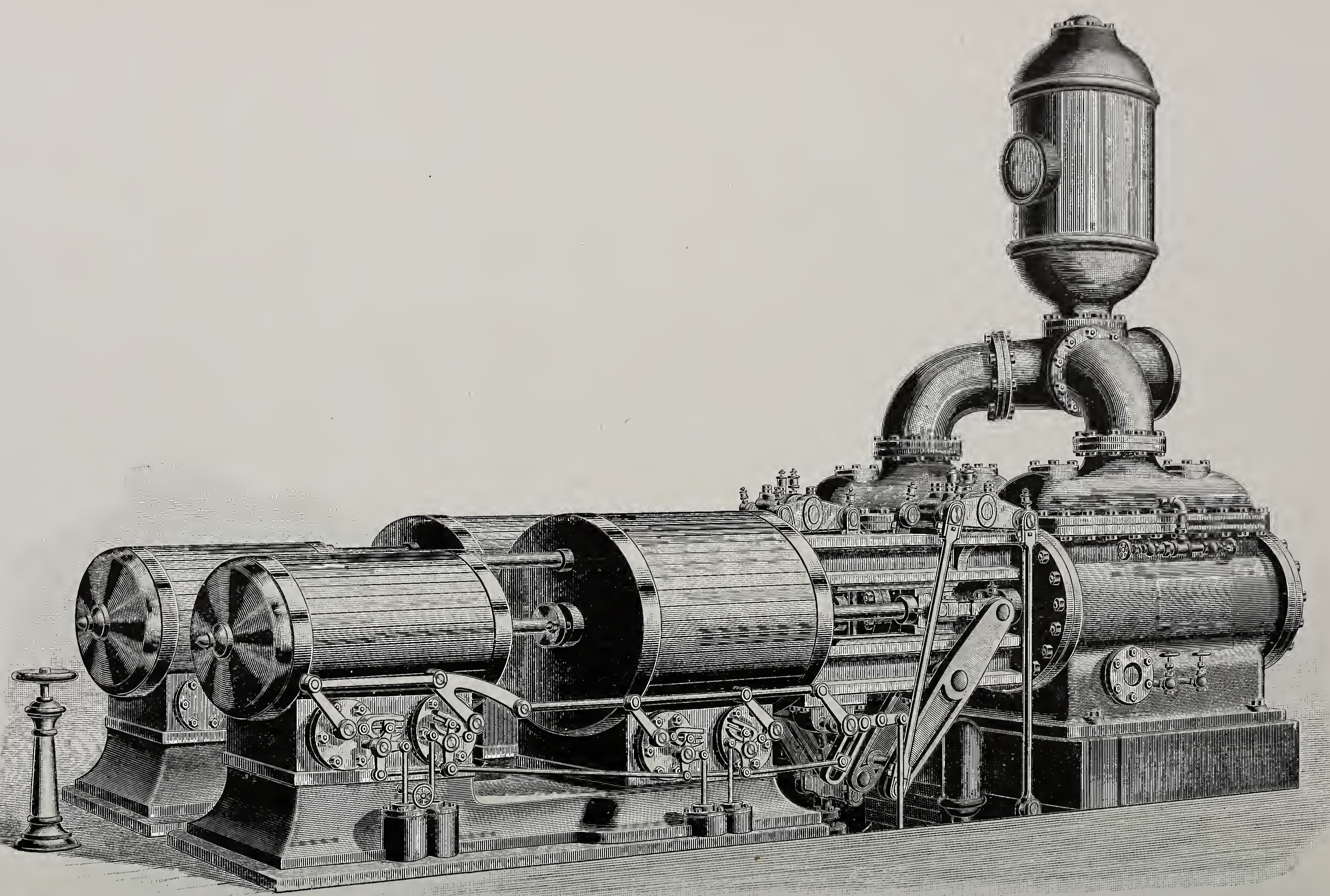
Mr. Woodbury received his elementary education in the public schools of his native city. Having fitted for college, he changed his plans and entered the Massachusetts Institute of Technology, taking the course in civil engineering. During his vacation periods he found employment in the offices of different engineers, in whose service he had opportunities for practical work in surveying, road-building, sewer construction, and the building of water works. He also secured six months' experience in a machine shop, giving attention chiefly to matters of interest to an engineer without trying to become a thorough mechanic. His first important professional engagement was as assistant to boards of engineers in making tests of water-works pumping engines in various eastern cities, beginning in 1873, under the supervision of James B. Francis, C.E., on tests of the first compound pumping engines used in America. For some time he was engaged in general engineering work, giving especial attention to steam power and hydraulics, and after an engagement to modify and improve the machinery of a factory at Rockport, he became its superintendent. His work in this position displayed such judgment, especially in organization and measures of fire protection, as to attract the favorable attention of the underwriters, and in 1878 he entered the employment of the Factory Mutual Insurance Companies as special inspector and engineer. While thus employed he made elaborate investigations reaching valuable results on questions pertaining to fire hazards in mills. The subjects which especially engaged his attention were lubrication, the fire

risks of electric lighting, and automatic sprinklers, and his contributions to their literature are of standard value. He also investigated by exact methods the problems of mill construction, and in the formulation of this work he introduced original methods in the mathematical analysis of the principles involved. Before Mr. Woodbury's time a movement in this direction had begun in New England, but was confined to the textile manufactories, and showed a wide diversity of ideas and expedients. His careful study of the best practice enabled him to reduce it to a system, which has found general acceptance and adoption. In these lines Mr. Woodbury's work is of the greatest practical value, and entitles him to rank among the engineers who have made substantial contributions to industrial progress.

But while chiefly known by the work in which he is a distinguished specialist, Mr. Woodbury has displayed a wide range of talents and much versatility. He has contributed liberally to the transactions of the leading engineering societies and to the files of the technical press. In 1883 his work on the "Fire Protection of Mills and the Construction of Mill Floors" was honored by the medal of the Société Industrielle de Mulhouse, in no other instance conferred upon an American engineer; and in 1885 he received from the city of Philadelphia the John Scott medal "for securing safety in the use of electric lighting in mills." In 1890 he became vice-president of the Boston Manufacturers' Mutual Insurance Company, one of the associated companies insuring manufacturers' property only, and has taken an active position in the advocacy of such methods of slow-burning construction and complete equipments of fire-protective apparatus for manufactories, especially in connection with the line of policy peculiar to the system of mill insurance with which he is affiliated.

Mr. Woodbury is a past vice-president of the American Society of Mechanical Engineers, member of the American Society of Civil Engineers, fellow of the American Association for the Advancement of Science, member of the executive committee of the Society of Arts of the Massachusetts Institute of Technology, corresponding member of the American Numismatic and Archæological Society, and has other dignified professional connections. Besides his contributions to the literature of engineering, he has done some general literary work, notably in connection with early colonial history.

In his professional and social relations Mr. Woodbury enjoys a wide popularity, and has a large circle of attached friends. Few engineers are better known or more respected, and very few have done more to merit honors. His special work has the advantage of immediate and permanent usefulness, and the fact that it is placed freely at the command of all for whom it has value entitles him to recognition as a public benefactor.



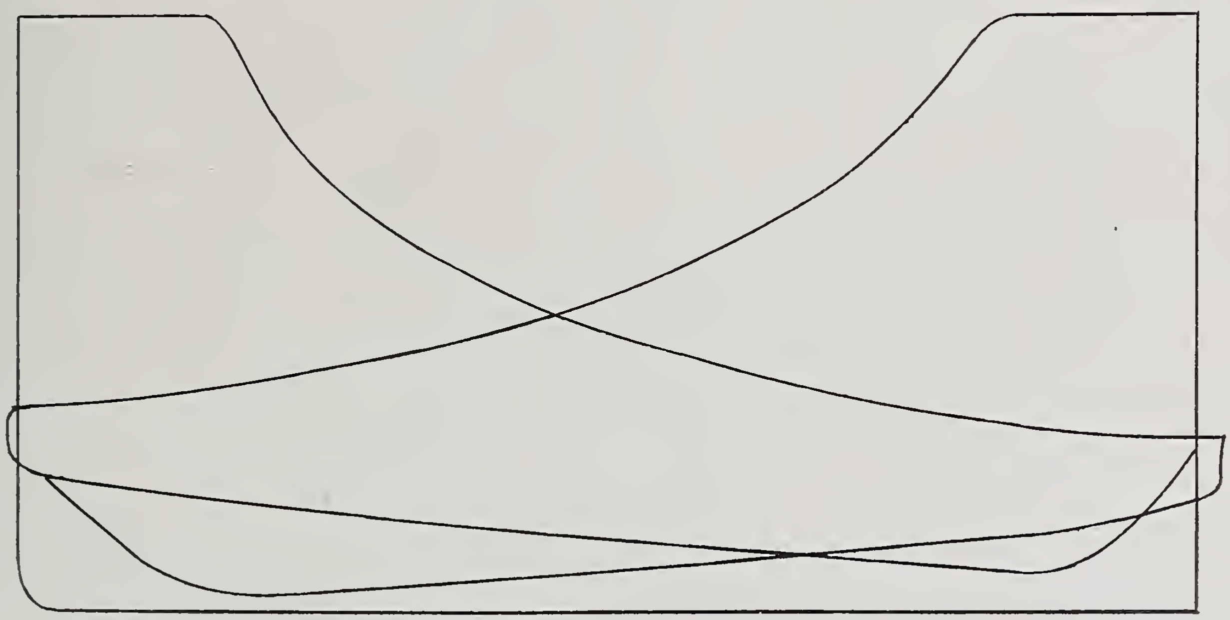
NEW PUMPING ENGINE, BUILT FOR EHRET & RUPPERT, BREWERS, NEW YORK.

A NEW TYPE OF PUMPING ENGINE.

By George de Laval, M.E.

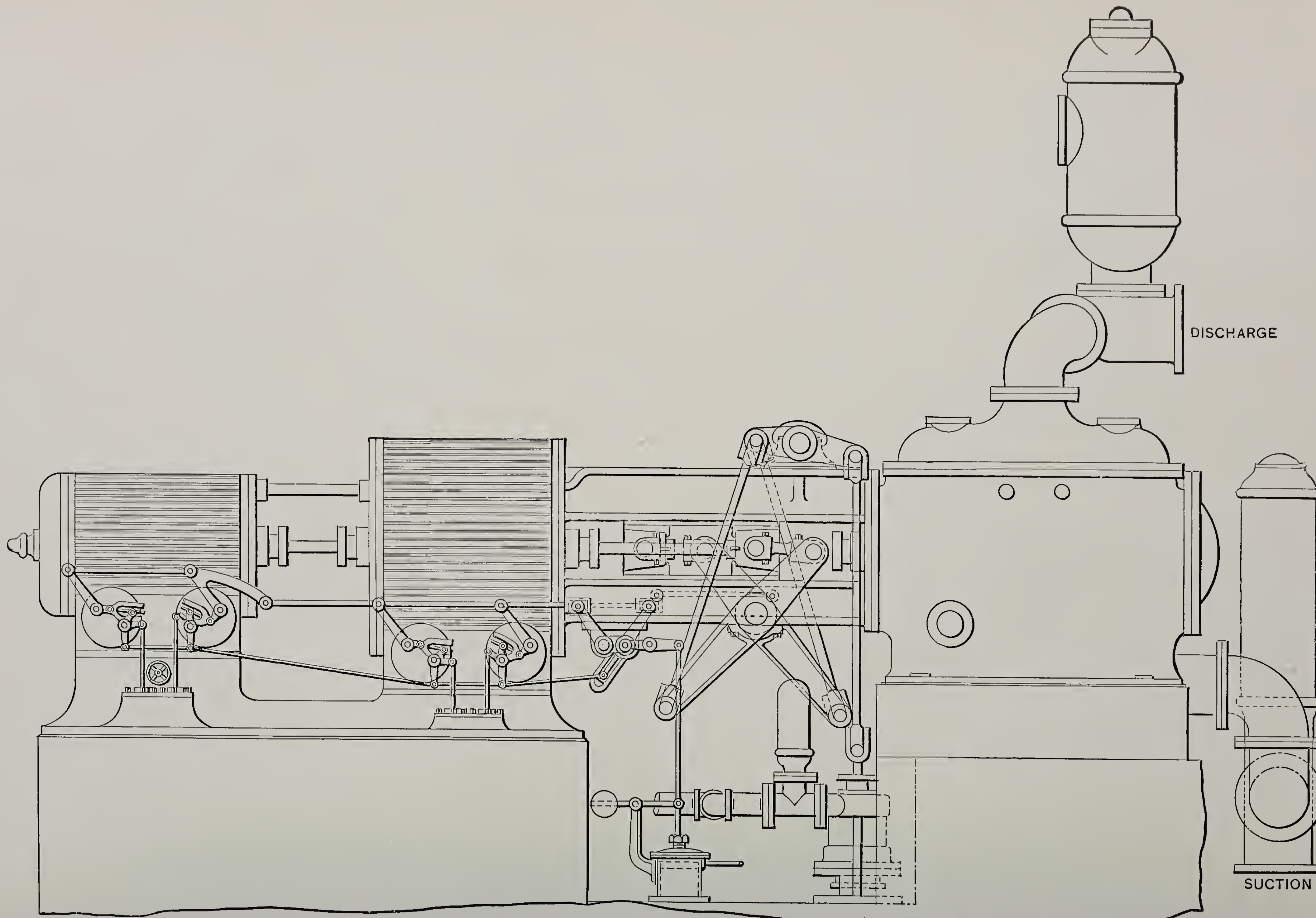
ON the opposite page is shown an illustration of a new type of pumping engine, two of which have been built for and are now in operation at the pumping station of the Ehret & Ruppert brewery, in New York, by the Groshon Pumping Engine Company, and were designed by Mr. Groshon, the president of the company.

The principle embodied in the design of this pump seems to render it peculiarly adapted to all purposes where a reciprocating motion is required to be produced, with the economical results attendant upon the use of steam acting expansively and under a cut-off.



The improvements embodied in the Groshon invention are to provide means for obtaining any degree of expansion, and at the same time preserve the features of a direct-acting duplex pumping engine,—*i. e.*, to exert a steady and uniform pressure on pump plungers without any vibrations to its water column, with as high degree of expansion of steam as used in any type of crank and fly-wheel engine. In order to accomplish this the usual methods of rotative motions are superfluous, and were entirely abandoned; also the use of oscillating cylinders was given up for its continued wearing on its packing. In order to keep the plungers of same tight, no complicated arrangements of air tanks, receivers, or charging apparatus were used, but single levers arranged properly and connected with the vertical compensating cylinders. The attachment by which the inventor has accomplished this single rig consists essentially of one or two vertical cylinders located below the foundation of the engine. These cylinders are connected directly with the discharge main of pump, and the pressure of same is exerted on the upper side of the plungers in the compensating cylinders. The piston-rod extending from the compensating plungers is connected through a vertical connecting rod to one end of a double crank, the other end of this crank being connected through connecting rod and beam with the crosshead. The connections will readily be understood from the engraving.

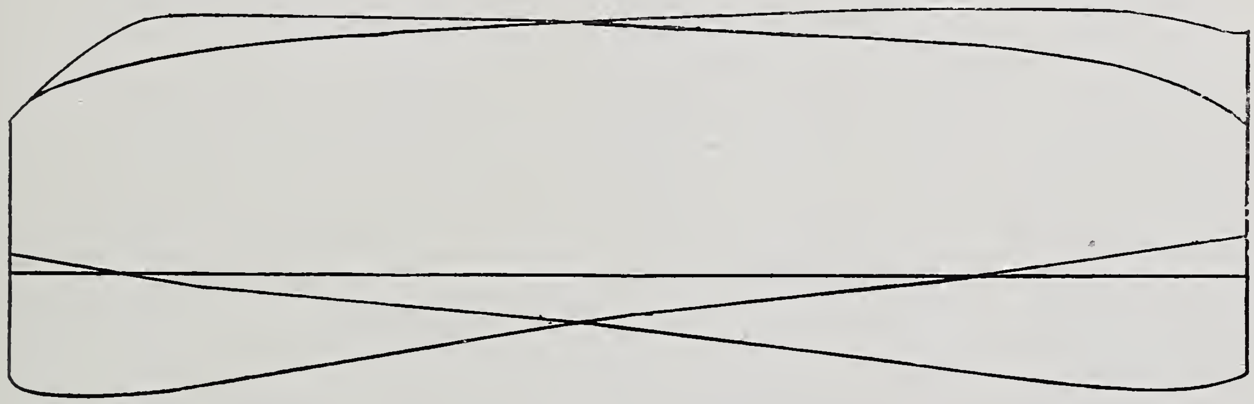
These compensating plungers act in such a way with respect to the motion of the engine as to resist its advance at the commencement of the stroke and assist at the end, the water exerting a



SECTIONAL VIEW OF NEW PUMPING ENGINE, BUILT FOR EHRET & RUPPERT, BREWERS, NEW YORK.

practically unvarying pressure at all points in the stroke. These compensating cylinders are either in pairs or single, and are so arranged as to relieve the engine from all lateral strain, performing the functions of a fly-wheel with the difference that in place of the energy of momentum in the fly-wheel it is replaced here by the constant pressure of water. The power on these compensating cylinders is controlled through a valve, and the size of cylinders is entirely unaffected by the speed of same, so that the same amount of expansion can be obtained at any speed, and there is no necessity of changing the point of cut-off necessary. The steam cylinders are arranged with rolling valves or flat valves, depending upon the work and size of engine, and the cut-off valves are arranged to suit the work. The cut-off valves are operated directly through cranks and levers, and no eccentrics or cams are used.

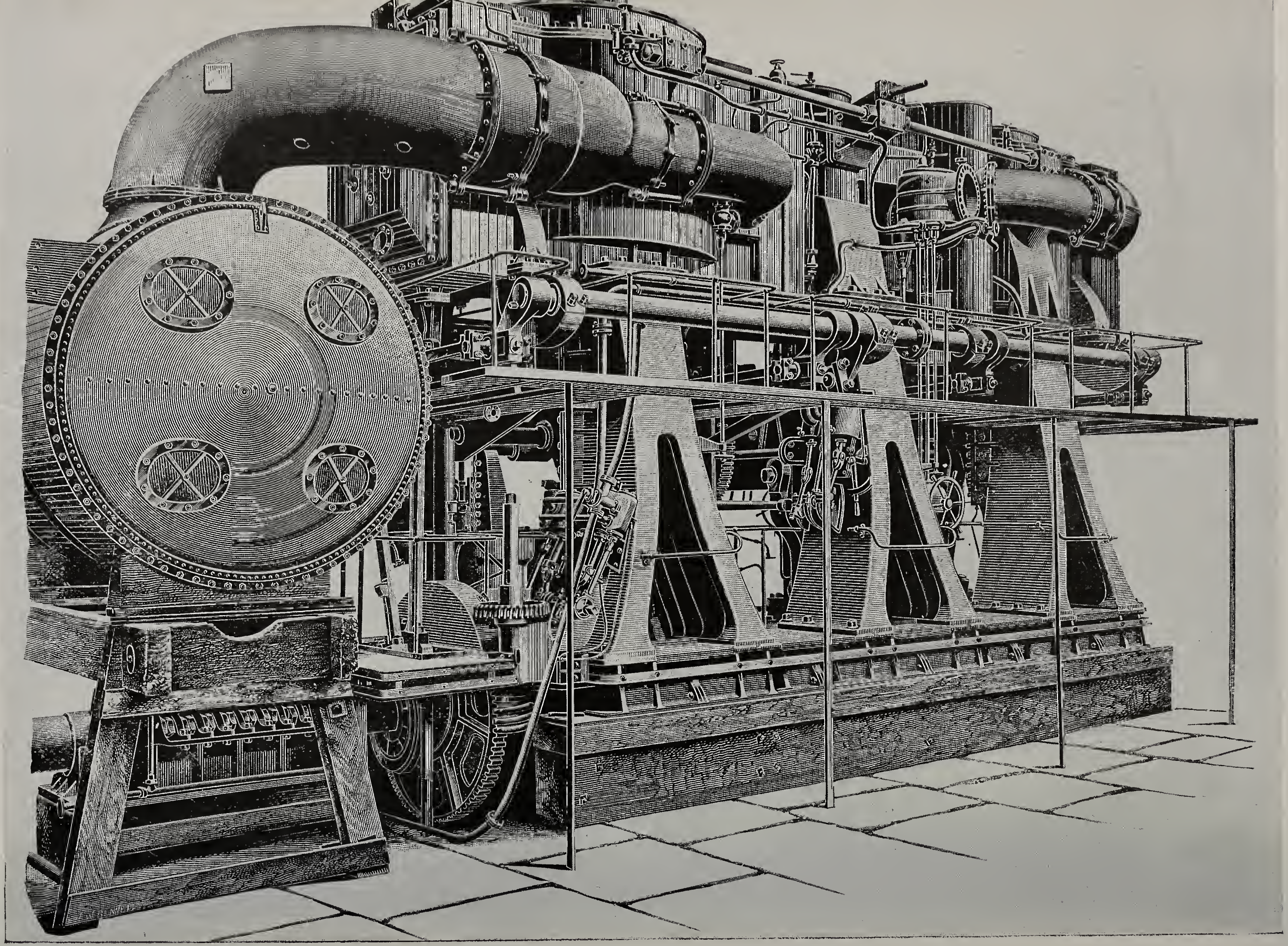
The engines illustrated have a capacity of 2,000,000 United States gallons each 24 hours at a water pressure of 70 pounds per square inch, and the indicator cards seem to prove as great a rate of steam expansion as can be obtained by the fly-wheel or rotative engine. If this is a fact, the economy



in engines under irregular or intermittent service. This last feature is of great importance in regard to its increased economy when working under such irregular conditions.

However, there has been added to these engines an automatic water balance cut-off regulator, which will fully control the engine under the hardest conditions and give the best economy. The engine can at any time, at the will of the operator, be made to work as a common duplex, thus giving opportunity to repair or overhaul the expansion gear, should it get out of order, and no air compressor or air tanks are must be greater, as the friction of this machine is much less than that of the fly-wheel engine, since there are no heavy wheel shafts, connecting rods, etc., to be kept in motion, consequently a larger portion of its power is applied directly to the work to be done.

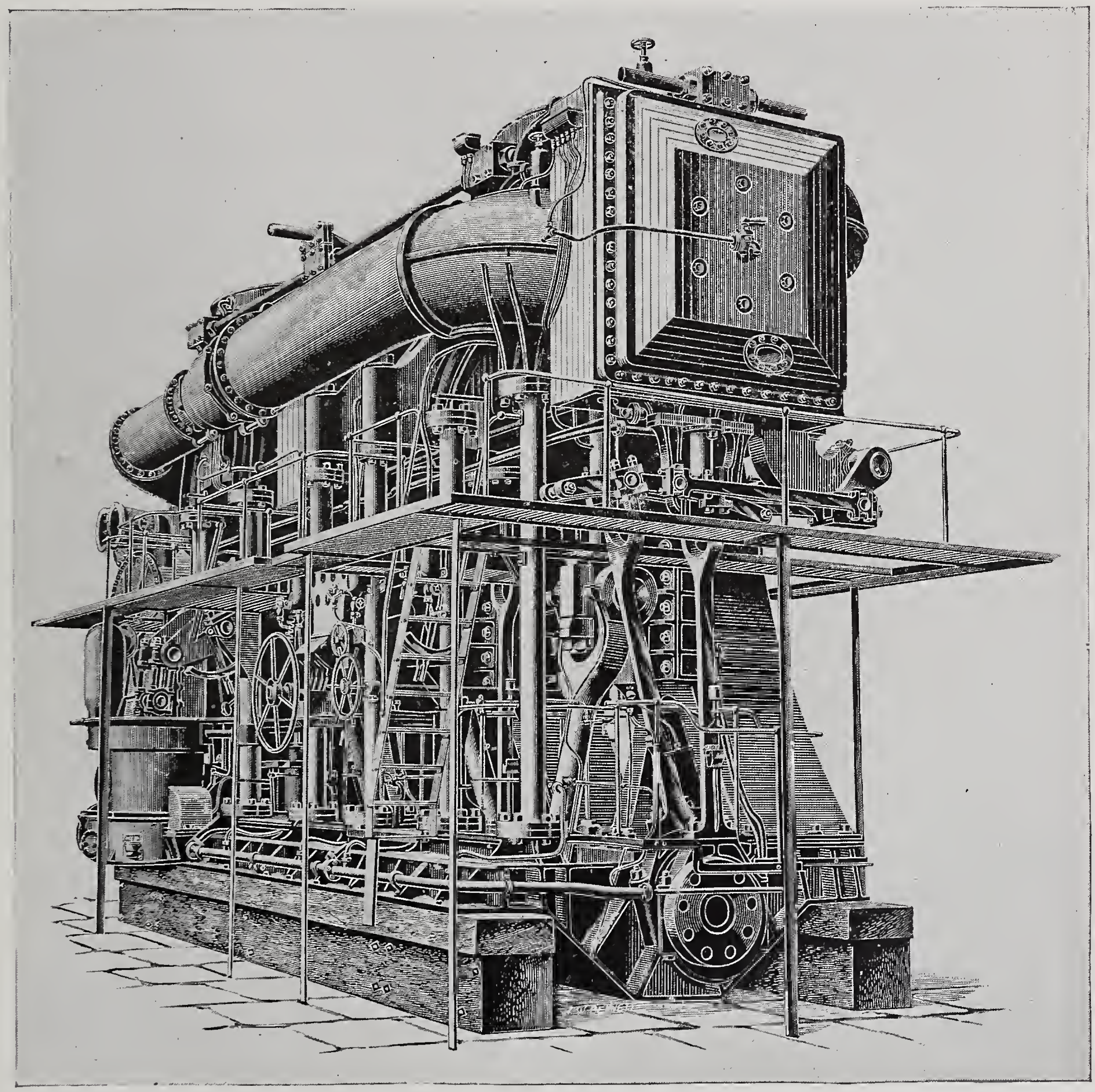
The engine that these cards were taken from was started immediately after its erection, and run for five weeks without a stop at a piston speed of from 95 to 110 feet, and during this performance it was operated by the same men who had formerly cared for the ordinary duplex pumps used for the same work.



ENGINES OF H. M. BATTLE-SHIP "RAMILLIES," CONSTRUCTED BY JAMES AND GEORGE THOMSON, ENGINEERS, LIMITED, CLYDE-BANK, SCOTLAND.

ENGINES OF THE BATTLE-SHIP "RAMILLIES."

THE main propelling machinery of the new British battle-ship *Ramillies* was designed and constructed at the works of Messrs. James and George Thomson, Limited, on the Clyde. There are two sets of engines of the triple-expansion vertical inverted type, which together are to indicate 13,000 horse-power under forced draught when making 108 revolutions per minute. Each set is placed in a separate engine room, the powder magazine being between; each is in all respects exactly similar, everything to the smallest detail being in duplicate The cylinders are forty, fifty-nine, and eighty-eight inches in diameter respectively, with a stroke of four feet three inches; they are entirely independent castings, and are connected together by steel stay-rods securely attached to each other.



ENGINES OF H. M. BATTLE-SHIP "RAMILLIES," CONSTRUCTED BY JAMES AND GEORGE THOMSON, ENGINEERS, LIMITED, CLYDE-BANK, SCOTLAND.

To still further increase their stability in case of ramming, etc., the column

heads have strong cast-steel struts fitted in between them. The receivers consist of copper pipes attached to gun-metal branches and expansion joint stuffing boxes. The whole of the cylinders are steam-jacketed, the working barrels of the high pressure and intermediate pressure being of forged steel, and those of the low-pressure cylinders of specially hard close-grained cast iron. The slide valves are on the sides of the cylinders, those for the high pressure being of the piston type, whereas the intermediate-pressure and low-pressure cylinders have flat triple-ported valves, there being two to each low-pressure cylinder, one on the forward and the other on the aft side. A special type of relief ring is fitted at the back of these flat valves, and balance pistons are supplied to all the cylinders to reduce the strain on the valve gear as far as possible. The valve gear is of the double eccentric link motion type, and is reversed by means of a double-cylinder engine attached to one of the cast-steel back columns of the main engines. To insure the maximum of efficiency and economy at all the powers required by the very varied exigencies of naval service, means are provided for altering the expansion in each cylinder independently of the others. The back columns are of cast steel, with separate hard cast-iron faces for the guides, and the front columns are of forged steel, thus giving a clear view from the starting platforms, which are arranged in the wings of the ship.

To insure the desired minimum possible weight, the main condensers, which have a collective cooling surface of 14,700 square feet, have both the casings and ends built up entirely of naval brass plates riveted together. The steam is condensed outside the tubes, the circulating water passing through them. The water is supplied by four large 16½-inch Gwynne's centrifugal pumps, each driven by an independent engine.

The crank shaft for each set of engines is in three separate interchangeable pieces, the cranks being set at 120 degrees to one another. The crank arms are cut away as much as possible for lightness and for convenience in fitting the centrifugal lubricators for the crank pins. The crank shaft, thrust, and propeller shafts are all hollow, an eight-inch hole being bored through their entire length, and they are each forged from a solid steel ingot. The thrust blocks and collars are of cast steel. The latter are lined with white metal and are of the horseshoe type, each being separately adjustable. The screw propellers are four-bladed, the blades, bosses, tail-pieces, and guards being of gun metal, and the bolts of forged naval bronze.

We are indebted to *Engineering* for the above description and the accompanying engravings, which are excellent representations of the engines.

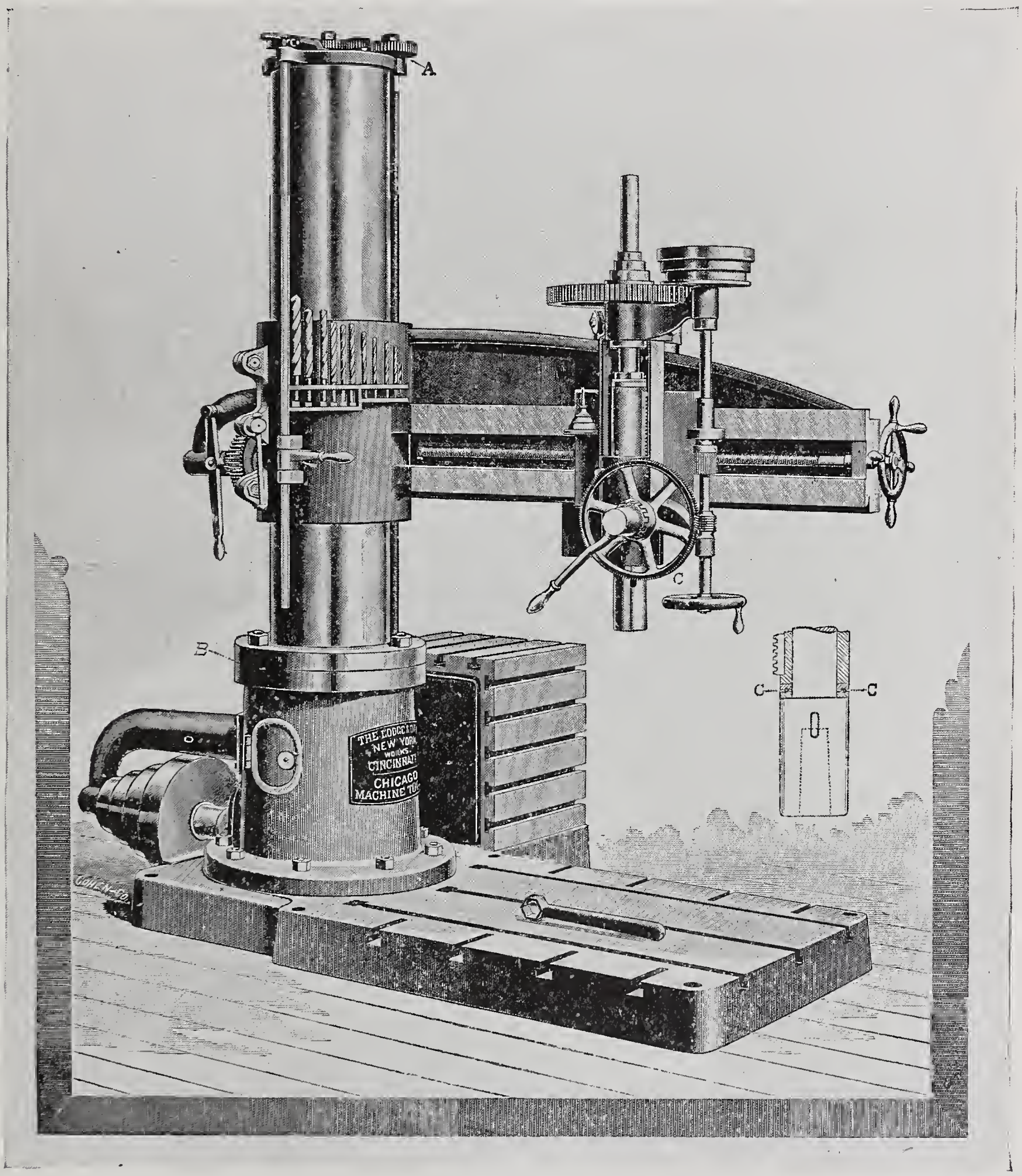
IMPROVED FIVE- AND SIX-FOOT ARM RADIAL DRILL.

ON the following page is illustrated a front view of a new radial drill with many novel features just brought out by The Lodge & Davis Machine Tool Works, Cincinnati, and designed by their chief draughtsman, Mr. Henry Dreses.

Radial drills now on the market are of two distinguished types,—one with fixed column and hinged swinging arm, and the other with column swinging around an enveloped stump fastened to the base and extending a portion into the column. The latter class, to which this drill belongs, have the advantage of being less complicated and to swing nearly the whole circle, but having no back support lack stiffness in many cases. This is very noticeable during heavy drilling at the extreme end of the arm, causing the drills to break by punching them through at the termination of the hole. To overcome this difficulty the builders of this tool have made the column of great weight and extra large in diameter. The lower part turns in an outside sleeve of increased diameter. The driving cone

is placed at the base of the drill, allowing it to be driven by a long belt direct from the countershaft, without bevel gears. The vertical driving shaft is placed in the center of the column, and receives its motion through a pair of miter gears from the cone pulley shaft.

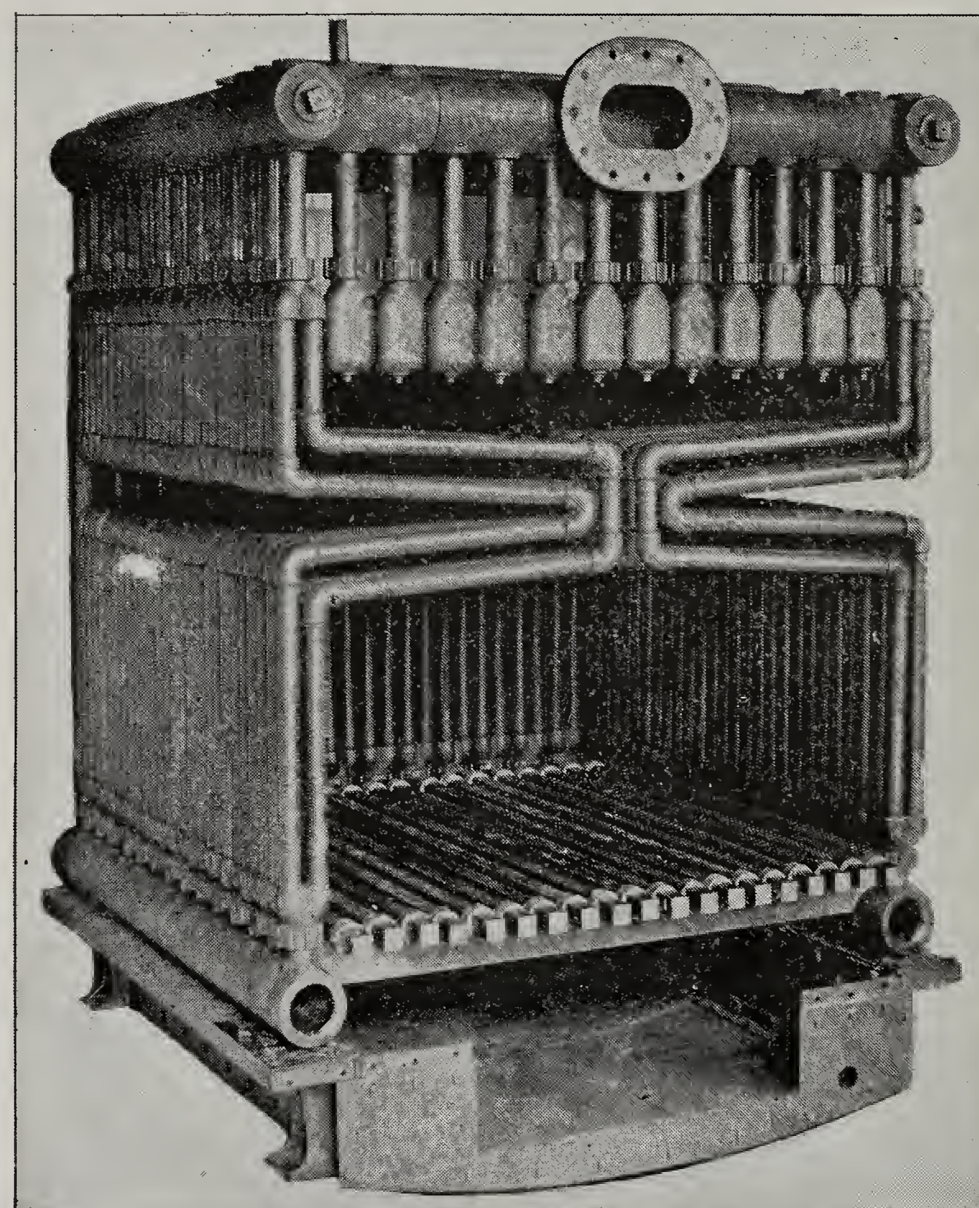
The bracket carrying the bevel gears, which slide on the vertical shaft, is attached to the swinging arm, and traverses in a slot provided in the rear of the column. Through this slot projects a short shaft driven from the inside bevel wheels, carrying a pair of sliding spur gears of different diameters, engaging alternately with the gears on the back shaft, shown in the rear of the drill. By this arrangement the change of the speeds is done rapidly, and at the same time brings the driving gearing close to the spindle. The entire internal driving mechanism is accessible from the outside, and can be taken apart without taking down the drill. The thrust bearing of the drill spindle, the column, and the elevating screw, denoted by letters *A*, *B*, and *C*, are provided with the Ross patent anti-friction ball bearing, which diminishes the friction to a great extent,



and avoids the oiling and cutting in these bearings. The swinging arm is very rigid, and is raised and lowered by power. The drill head has an extra large bearing on the swinging arm, and is furnished with the builders' patent quick return, well known from their line of upright drills. These drills are furnished with double friction countershafts arranged for tapping.

ALMY'S WATER-TUBE BOILER.

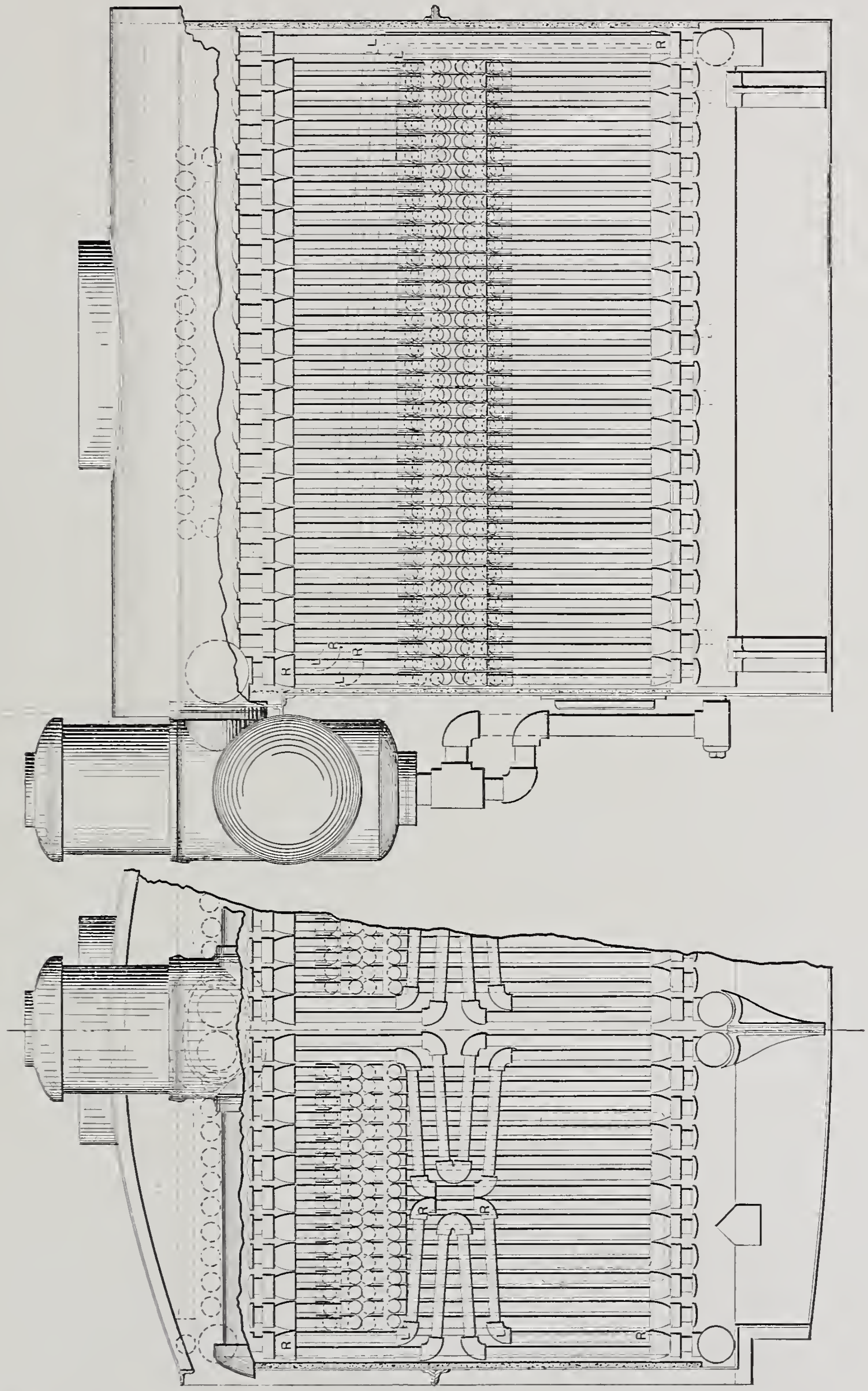
WITH the high pressures now required and the manifest tendency to still further increase the pressures in marine boilers, it cannot be very long before an entirely new form of marine steam generator will become absolutely necessary. Various kinds of water-tube boilers have been designed during late years, both in America and abroad, and they are being tried in torpedo boats, tugboats, and small craft. Some of them are bearing out so well in actual service what their inventors claimed for them that it is only a question of time when water-tube boilers will be generally adopted for merchant vessels. Of the water-tube boilers brought out in America, one of the latest is that of the Almy Water-Tube Boiler Company, of Providence, R.I. One of these boilers, weighing 5½ tons, was fitted in the U. S. torpedo boat *Stiletto*, where it has shown itself capable of supplying steam for a triple-expansion engine indicating 600 horse-power when driven with forced draught.



ALMY'S WATER-TUBE BOILER, BUILT BY ALMY WATER-TUBE BOILER CO., PROVIDENCE, R. I.

The heating surface of the boiler put into the *Stiletto* consists of one-inch steel pipes, which are disposed as shown, making their turns with bends and elbows connecting to four-way branch fittings, and these are connected by a union to flange nipple at top and bottom manifolds. There is a manifold in

the form of a rectangle below the grates, with a mid-drum in the center at the back cross-section which forms the base of each furnace. The top manifolds are four sections running parallel, connect- Between the vertical pipes which form the middle wall of the furnace is placed a wall of fire-brick which completely divides the two furnaces. The furnaces are each 31½ inches by 67½ inches,



ALMY WATER-TUBE BOILER AS PLACED IN U. S. TORPEDO BOAT "STILETTO." BUILT BY ALMY WATER-TUBE BOILER CO., PROVIDENCE, R. I.

ing into an enlarged heater across the front. The crown of the fire-box is formed by the elements which rise from the back of the boiler and extend across at right angles to the heating surface. making the total grate surface 29½ square feet. The total heating surface is 1100 square feet, 187 square feet being subjected to the radiant heat of the furnace.

The system of pipes when completed is cased in sheet steel lined with asbestos, the fire-box being in addition lined in front with fire-brick. This casing is made in sections, and bolted to angle iron in such a way that any section may be readily removed, enabling the repairs to be made without trouble. The outside dimensions of the casing on the *Stiletto's* boilers are 76½ inches in length by 79½ inches in width, and the total height from bottom of ash-pan to crown of hood is seven feet. The distance from bottom of ash-pan to top of grate is twenty inches, as is also the distance from top of grate to crown of fire-box. The water is fed to the boiler in such a manner that it is subjected to the heat of escaping gases just before they each the flue, which, of course, conduces to economy and efficiency. Steam is taken through a separator which is placed in front. The boiler is what is called non-explosive, being capable of carrying far higher pressures than those designed for it, and in case of the failure of a tube the consequences are not likely to be serious, especially since the section in which the failure occurs can be stopped off, while the balance of the boiler goes on performing its duty. The water level is said to be very steady, and it is found that there is no priming when using salt water. The boiler steams very quickly, it being possible to get steam in from ten to twenty minutes.

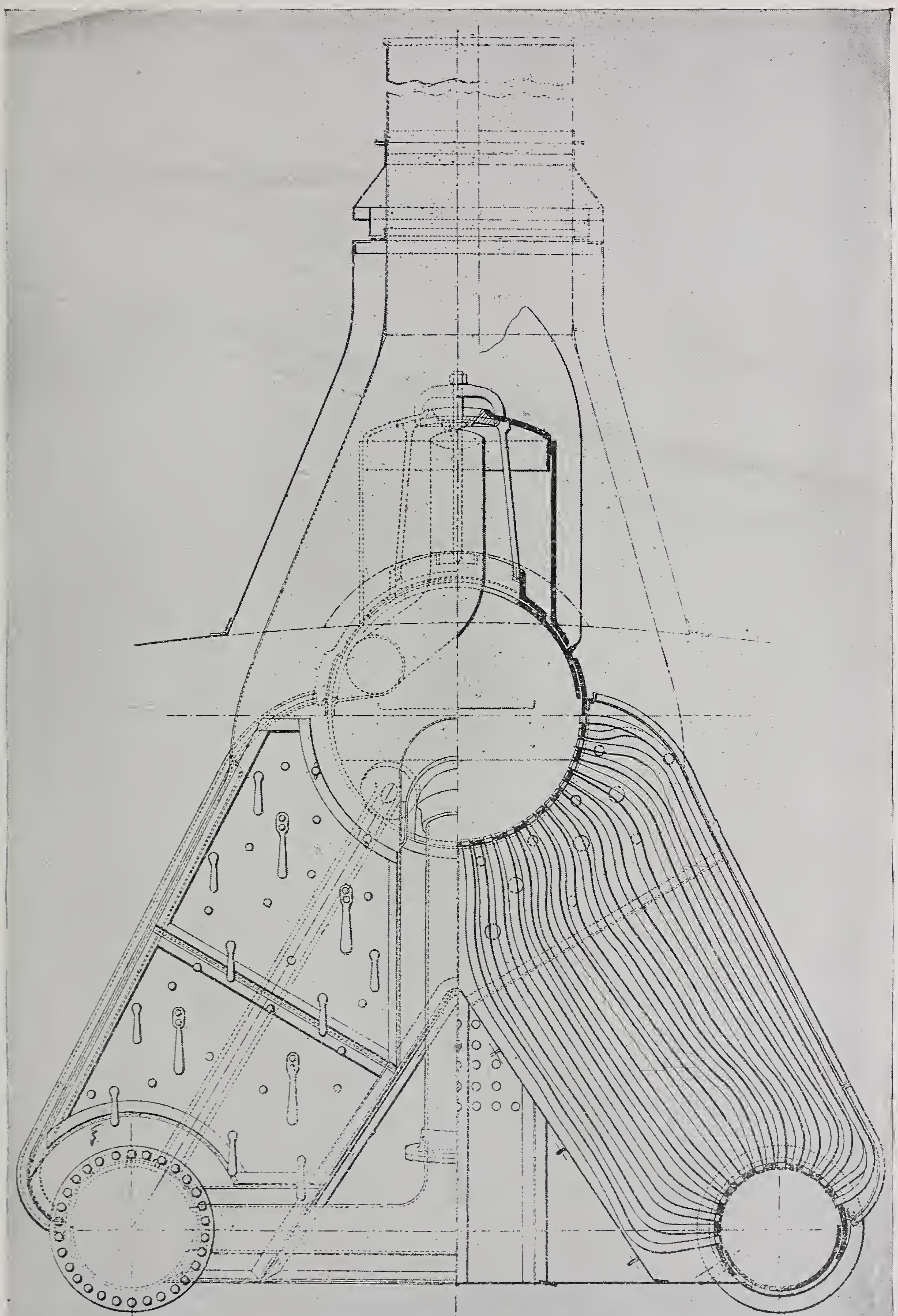
The *Stiletto* is ninety-four feet long, eleven feet beam, four feet ten inches draught of water, and thirty-one tons displacement. With her former boiler generating steam at 134 pounds pressure, the indicated horse-power was 359, giving a speed of $18\frac{22}{100}$ knots. The boiler in question had thirty-seven square feet of grate surface, and 607 square feet of heating surface. Bituminous coal was used, and the air pressure was 1¼ inches at the stoke-hole. With the Almy boiler above described, 140 pounds of steam was easily maintained with one-inch air pressure, using anthracite coal.

NORMAND'S WATER-TUBE BOILER.

THE French government is determined that its fleet shall have torpedo boats equal, if not superior, in speed to those possessed by any other nation. The performances of its latest boat, No. 149, show that the French engineers are unquestionably not lacking in skill or mechanical instinct. The most remarkable feature in this boat is the boiler, shown in the annexed engraving taken from *The Engineer*, London, and which was designed by M. Normand. The French authorities do not wish to have the details made public, so that only a transverse section can be given, which will serve to make the general principles of its construction clear. The tubes are of copper and brass. The downward circulation is maintained, as in the du Temple system, by pipes of large diameter at the back end of the boiler, uniting the upper receiver with the two lower horizontal water tubes. The grate surface is thirty-five and a half square feet. The heating surface is 1895 square feet.

At the time of her trials the boat had just come out of dock, and her bottom was clean, and had received a coat of the regular French naval anti-fouling composition. The water was smooth, and the weather fine, conditions favorable to the boat. On the other hand, she had on board her full fighting equipment, and enough fuel to enable her to steam 1800 miles at a speed of ten knots. Her displacement was a little over seventy-five tons. The area of her midship section was 34.5 square feet. Her draught of water on starting was forward three feet five inches, and aft four feet two and three-quarters inches. She burned during the two hours' run, when steaming at full speed, in round numbers 4826 pounds of briquettes, during which time she ran a little over forty-nine knots. On the completion of the two hours' run she was taken again for three runs over the measured mile, when speeds of 22, 26, and 23.4 knots were attained, giving, with the average obtained during the first three runs, a mean of means of 24.64 knots per hour.

The boiler gave no trouble whatever, and was found to be, when opened for examination after the trials, in perfect condition.



SECTIONAL END VIEW OF NORMAND'S WATER-TUBE BOILER.

THE KEYSTONE REVERSIBLE MOTOR.

THE Keystone reversible motor was designed by Mr. C. J. Sturgeon with a view of developing a motor adapted to meet the demand for a practical elevator motor. It is claimed that this motor is capable of receiving the full force of the current, for starting it under load, without the intervention of a resistance box or other artificial resistance outside of the machine itself. It is started, stopped, and reversed by means of a special switch, shown in Figs. 2 and 3, which operates to reverse the current through the armature, as well as to cut out both the incoming and outgoing lines for stopping the machine.

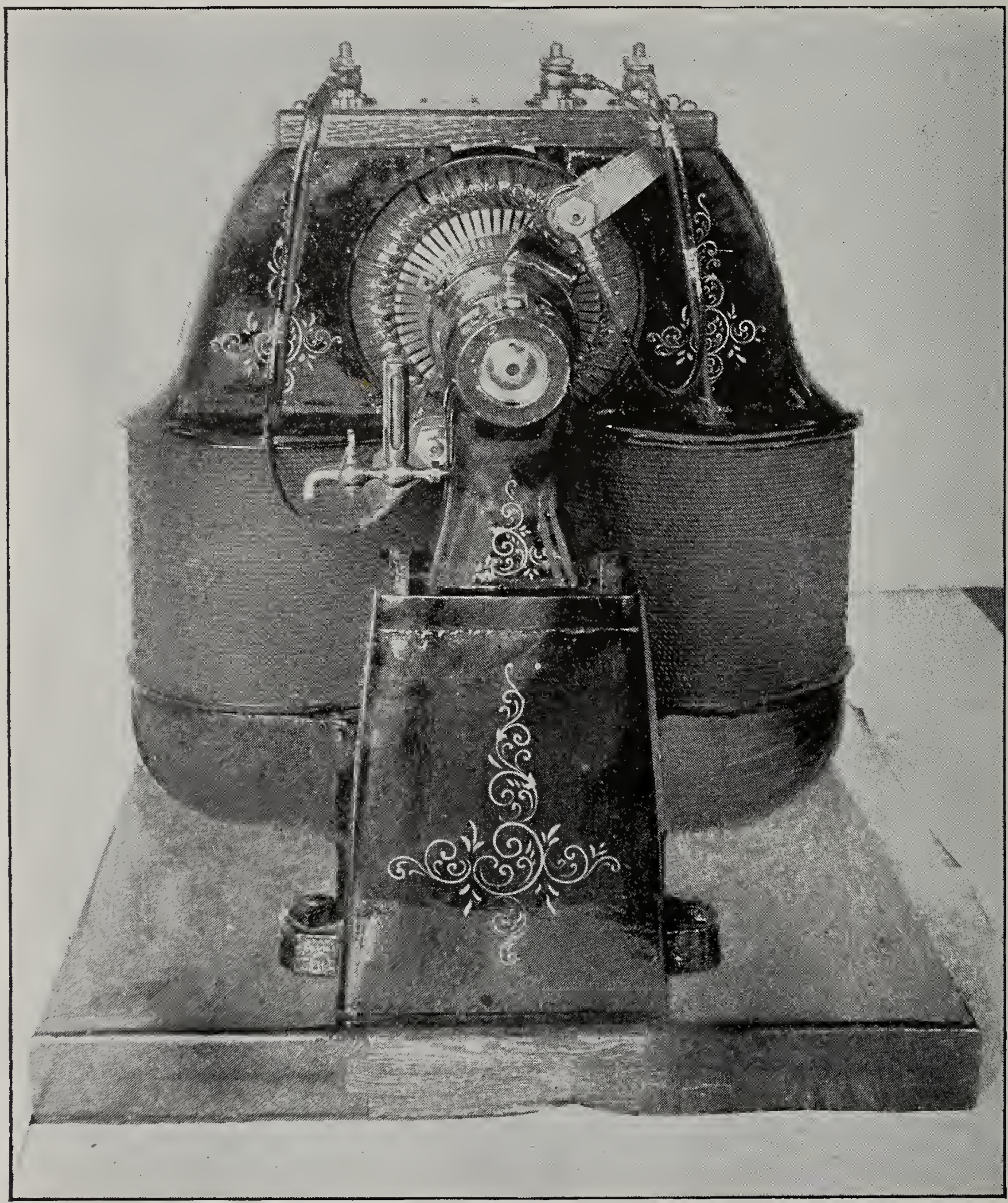


FIG. I. THE KEYSTONE REVERSIBLE MOTOR.

When in position shown in Fig. 3 the motor is at rest. When in position shown in Fig. 2 the motor is in circuit running in one direction, and is reversed when the arm is moved to the opposite side.

C. J. STURGEON.

The sprocket wheel is insulated from shaft to switch by means of a fiber disk fastened to the flange on shaft, with sprocket wheel secured to this fiber disk, which prevents any ground through hand cable. A fiber insulation is used in center of switch shaft to separate the two sides of the circuit. The feeder lines are connected at any two of the four points, connecting terminals being provided at each of these points.

The terminals, Fig. 3, are for connecting switch and motor, motor having a like number of terminals with corresponding letters, between which wires are to be run. To simplify the work of connecting, each binding post on motor is lettered, with like letters on switch terminals. Wires are run from letters on switch to like letters on motor. For convenience in wiring, provision is made for connecting to either side of switch.

The arm shown in Fig. 3 is pivoted on shaft with springs on each side. This arm passes between the jaws on either side, and is held by friction sufficient to make a snap break, and is so timed that all contacts are closed before the circuit is completed by this arm engaging with jaws. When circuit is broken by switch all contacts are on until arm leaves the jaw, making this the only point where any of the injurious effects of circuit-breaking occur,

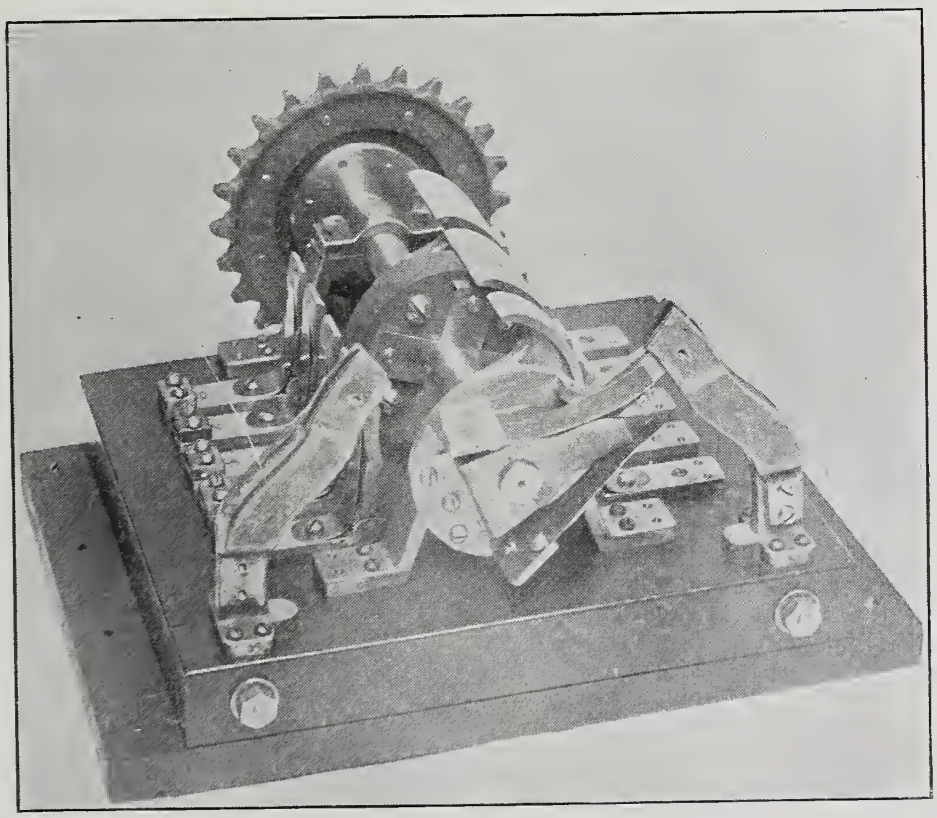


FIG. 2. THE REVERSING SWITCH, SIDE VIEW.

and on account of its snap action there is very little here. The base of these switches is of hard wood, shellacked, as there is but little arcing at points where circuit is broken, and as they are a good distance from the base it is considered safe. The current reaches the two outside contact plates of switch through the shaft. The center plate, being insulated from it, serves as a bridge plate.

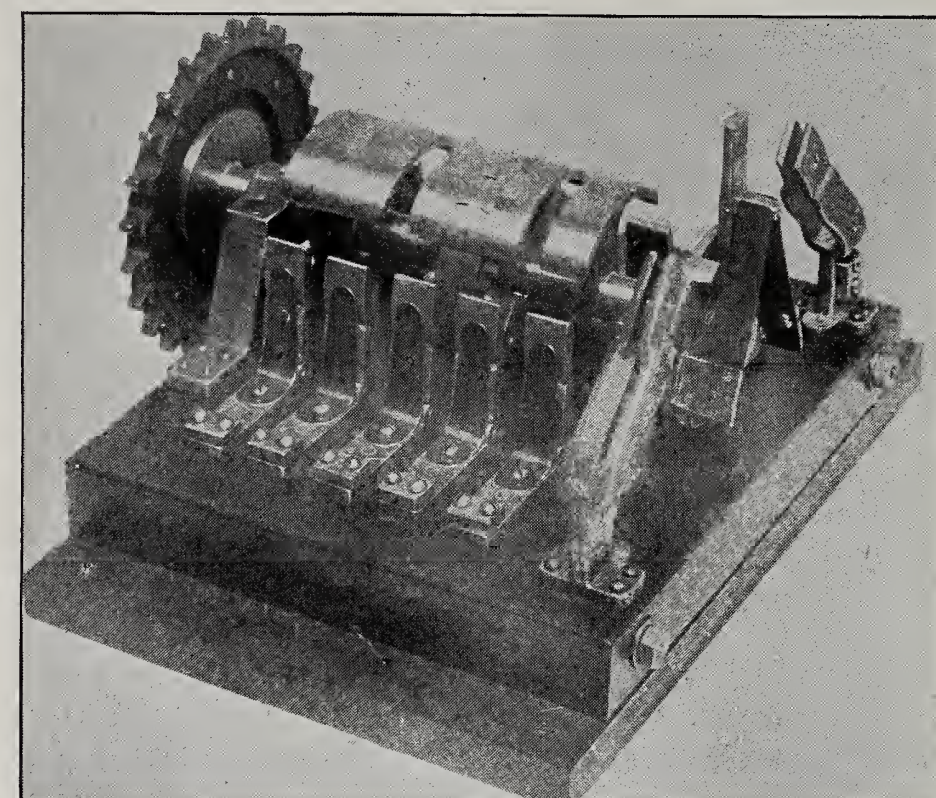


FIG. 3. THE REVERSING SWITCH, FRONT VIEW.

The switch for elevator service is usually connected by sprocket chain to break mechanism, operating simultaneously with break. The same switch is also made with hand lever, for use in operating motors driving machinery where a reverse motion is desired.

There are reversing elevator motors made, prominent among which are the Otis Bros. & Co.'s and the American Elevator Co.'s Both of these have devices for controlling the current by means of resistance, which is gradually cut out as the motor increases in speed.

In the method here described no resistance is used, and the parts are of such simple construction that it is claimed but little attention is required to keep it in perfect working order. About seventy of these motors are now in use, some for over two years, without the loss of an armature by burning out.

The type of this motor, shown in the accompanying cut, is adapted especially to be belted to a pulley on the worm shaft of the elevator and is made in sizes from three to twenty-five horsepower. These motors are made by the Keystone Electric Company, of Erie, Pa.

Reflections and Observations.

SOME queer stories come from the West, but quite near home, up in the lumber districts of Michigan, there exists a creamery which is worth talking about, according to a Detroit paper :

"I was spending the night in a country town not long ago," said the drummer at the dinner table, "and in the evening, before bedtime, several of the natives collected at the tavern, and we sat around on the porch talking. One of the residents was telling me what a fine country they had about them.

"'Why,' he said, in all earnestness, 'Jack Binsy, who has a dairy farm ten miles from town, gets a million pounds of butter a week from his cows.'

"'Aw, come off,' I said, with a laugh, 'you can't make me believe any such stump speech as that.'

"'But it's true as preachin',' he insisted.

"I demurred again.

"'Ain't it so, Henry?' he asked appealingly to an elderly man sitting next to me.

"'Well, I can't say as to a million pounds,' was the cautious reply, 'nor just how much exactly; but I know Jack has got three saw mills on his place and some Leffel water-wheels, and he runs 'em entirely with buttermilk.'"

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IT IS ever thus. When the new keyless watches were put on the market, a short time ago, we heard the name of a new inventor. But like nearly all "new" things of the present century, the keyless watch is an old idea.

Napoleon I. was the owner of a wonderful specimen of this species of keyless timepieces. It was continually kept in running order by a small weight at the end of a lever which worked on a weak spring. Every step taken caused a small "dog" to drop into the cogs of a tiny ratchet-wheel, this in turn acting on the barrel to which the mainspring was attached; ordinary movements about the house were sufficient to keep the spring tightly wound up.

In the Kensington Museum, London, there is a pedometer, operated in a similar manner, combined with a watch, so that the one instrument tells the time and the distance walked by the wearer in a day or any other given time.

There is a watch on exhibition at the United States Patent Office which is wound up by the simple act of closing the case. It also has an attachment that throws the winding device out of gear as soon as the spring is well wound up.

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ABOUT thirty years ago, when there was some idea of harnessing Niagara to do the work that is now proposed for it, an eminent engineer was called upon for his professional advice. He journeyed through Buffalo, and before settling down to business he thought he would "take in" the falls. Every one knows what the reputation of Niagara Falls was before the American and Canadian governments made public parks of the vicinity.

The engineer from time to time was asked for five or ten dollars, or whatever the fee was in order to gain certain advantage points for observation.

At last, with his pockets practically empty, he got to the bridge at Goat Island.

As he lived in Brooklyn, he had in his pockets some ferry tickets, and in an absent-minded manner he took one from his pocket, laid it down upon the

window of the toll-house, and passed on.

"Hold on there," cried the toll-man. "Pay your fare."

The engineer suddenly remembered he had made a mistake, and going back to the window said: "Excuse me, sir; forgot where I was; thought this was Fulton ferry. How much do you want?"

According to the story, the toll-keeper, thinking he had a greenhorn, said: "Five dollars, please."

"What's that?" incredulously exclaimed the engineer.

"I said five dollars," repeated the toll-keeper.

"Well, my friend, I came here to *look* at the falls; I don't want to *buy* them."

THE story is told of another engineer who took a different method of settling a small bill, or, to be more accurate, of not paying it the second time, for he assaulted the collector who called for a settlement, and was arrested for it.

"What did you do to this man?" asked the district attorney.

"I didn't do nothing."

"Well," continued the attorney, "give us your version of the case."

"I hope you will believe it, although it does seem strange; but when I told him I had paid the bill *once*, and wouldn't pay it again, the scoundrel began to abuse me."

"What did you do then?"

"Well, I remonstrated with him."

"In what way did you remonstrate?"

"Well, I don't exactly know, but I think the connecting rod was pretty well bent up when I got through."

SPEAKING of Niagara reminds me of a story I heard the other day of a foreign gentleman who was paying his first visit to America. He had heard a great deal about Niagara and the great plan of supplying 100,000 horse-power. So he decided to visit the falls and examine this stupendous piece of work.

He had also heard that Chicago was worth seeing. So during the evening he called the head porter to him, and inquired if he thought it was worth while for him to see these two places.

"Yes, to be sure it is," replied the porter.

"Well, then," answered the intending visitor, "order me a carriage at eight in the morning, and I guess I will go and see 'em. If anybody calls, say I will be back for lunch."

ANOTHER story of Niagara that I heard the other day was about a sea captain who had never been to sea. All his navigation had been in New York harbor. One day the company by whom he was employed decided to make him a real captain, and instructed him to sail for Liverpool, where his new ship would be found awaiting him.

The captain didn't like the idea of leaving New York, but set out making preparations for the journey.

Coming down to the office of the company to receive further instructions, he was asked, "How do you intend to go, captain?"

"Well, I guess I'll go about like the man who went over Niagara Falls last week."

"How is that?" he was asked.

"Very reluctantly."

COMING into a drawing room of a small iron-manufacturing establishment in the South one day, a gentleman stood intently gazing upon a man who was making some tracings.

"How do you make your drawings?" asked the visitor. "By rule?"

"Divil a rule, sir."

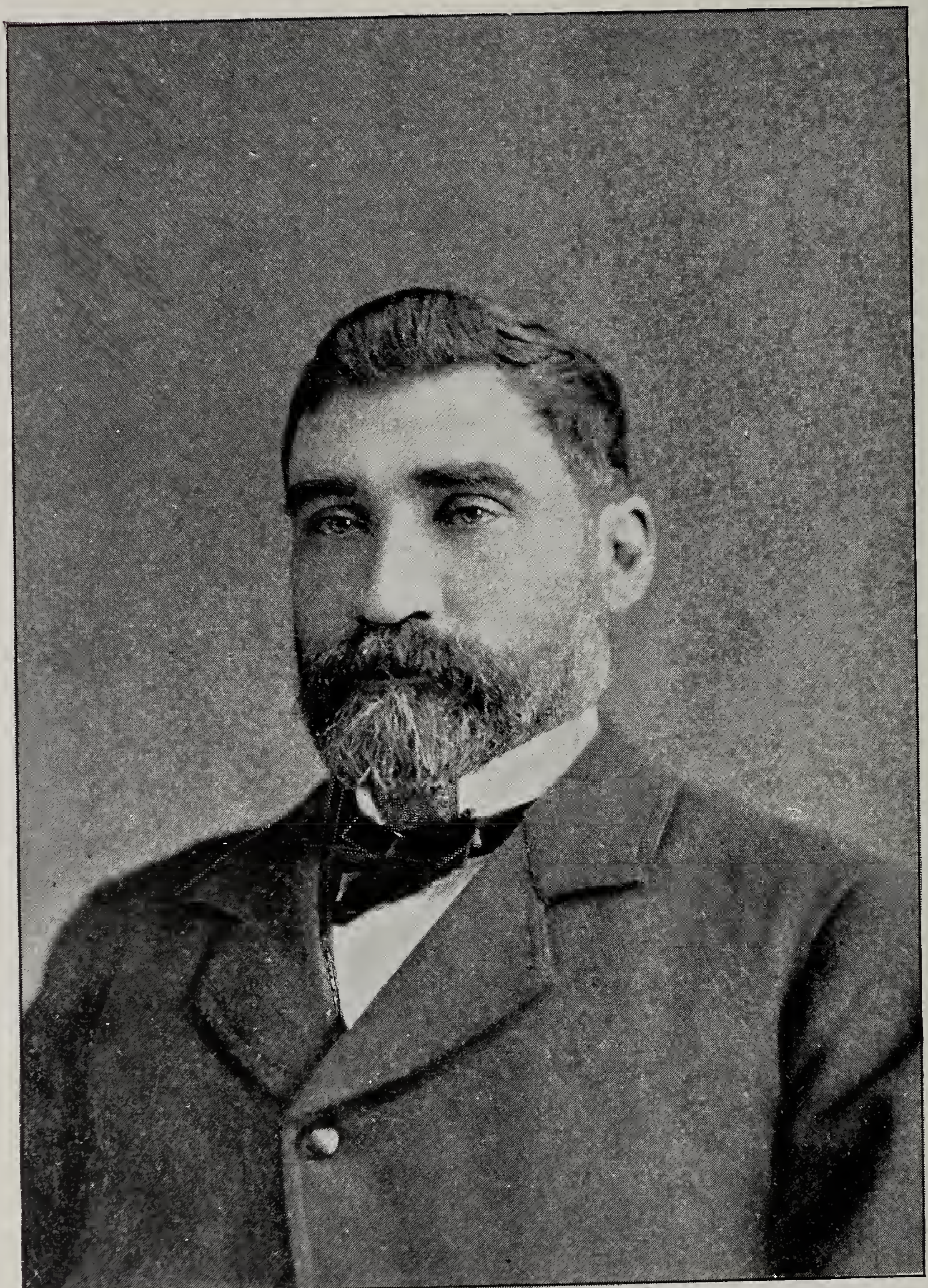
"I suppose you draw by scale, then?"

"Nary a scale, sir."

"Well, how do you draw, then?"

"By main strength, bejabers."

THE OBSERVER.



JOHN RICHARDS.

CASSIER'S MAGAZINE.

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THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

By Otto von Geldern.

THE Technical Society of the Pacific Coast, the most important organization of the kind on the western side of our immense country, is peculiarly situated in its environment, of which we will, in the first place, make some explanation.

In that section of the United States known as the Pacific coast, twelve hundred miles long, averaging from two hundred to four hundred miles wide, and embracing, in whole or in part, six states and territories, there is in proportion to population a much greater amount of what might be called "technical activity" than in the eastern states. What this proportion may be we cannot say, because even agriculture, in most of its phases, is of an engineering character, and when allied with irrigation it becomes clearly so.

Not only is the amount of engineering, in the full meaning of its technological sense, more extensive in proportion to population than in the eastern portion of the republic, but the pursuits are infinitely more diversified. In this respect there is no parallel that can be referred to. The narrow market, or rather its diffused condition, prevents the organization and centralization of industry. There is a cosmopolitan population furnished from all parts of the world : people who have brought with them their skill and acquaintance with the useful arts and professions. The search for a mild climate and the sanitary conditions that exist on the middle coast have caused an influx of all classes much faster than assimilation was possible. These people cannot be idle ; hence there is scarcely a department of human industry that is not in some way represented among the multifarious pursuits of the Pacific coast.

Among these interests is mining, devoted to nearly all kinds of minerals, involving numerous reduction processes with the plants for carrying them out, requiring mechanical apparatus the most complicated and extensive that has ever been produced in any country for procuring, raising, and conveying minerals and water.

Hydraulic operations have been carried on to an extent and of a character that have made the Pacific coast a center of research. This field has produced many marked advances in the conservation, conveyance, raising, and distribution of water ; also in the application, under peculiar circumstances, of high heads to motive power, demanding novel mechanical devices, operating under new methods that are just now the subject of interesting research. In this connection, too, is that vast field of special engineering which has just taken

a name and place as a separate and extensive branch. We allude to irrigation, or the application of water to arid soil, and to various growths thereby enabled, involving not only the physical conditions of collecting, conveying, and distributing the life-giving element, but also its effects upon the soil and the chemical problems that require the consideration of the irrigation engineer.

In the same connection, again, is the variation of precipitation, and the physical phenomena that attend a difference therein, which is as 3 to 60 in a distance of 1000 miles of the coast line, causing characteristics of streams, growths, and climate that afford an endless opportunity for technical research.

In the way of natural phenomena, this country abounds with strange and fascinating curiosities, presenting chemical and geological problems that invite thought and careful study. Hundreds of thermal springs, from 60° to 212°, giving off vapor here and laden with mineral there, are found in many parts of the coast, in regions that are as wild and romantic as they are picturesque.

The existence of subterranean water in the gravel strata of sedimentary lands and the artesian basins of wonderful extent also furnish to the engineer and geologist problems of not only scientific interest, but intimately connected with the value of land and the prosperity of important industries depending on subterranean water supply.

The approaches from the sea and the accessibility of the coast to shipping, the safety of the numerous coast harbors, and the navigability of the rivers for the purposes of water traffic are special fields in which the Pacific-coast engineer will find ample opportunity to exhibit his skill and knowledge. The time is near when the question of coast harbors will be a very material one to the interests of our states, and with it the improvement of the navigable rivers will go hand in hand. Opportunities are offered for original research in this field which cannot be exceeded anywhere in the world. The successful drainage of the great Sacramento valley alone suggests a vast problem, which has become a most vital and important one to a wealthy and prosperous population of farmers and horticulturists. Intimately connected with this problem is the successful restraint of mining *débris*, a question which is still awaiting its practical solution, and to which many intelligent and industrious communities scattered throughout the Sierras are looking with an unabated interest. There is work to do, and enough of it: work that will bring manifold reward to the engineer who is called upon to battle with this one great problem alone.

The improvement of harbors and rivers and the lighthouse service of the coast are carried on by the government, executed mainly by corps of engineers. Prominent in this particular branch of the technical profession is Colonel George H. Mendell, of the engineer corps, the first president of the Technical Society, a gentleman who has been for many years closely identified with all the noteworthy engineering problems of the coast. Allied to the improvement of the harbors is their proper defence, a subject that is certain to have the fullest attention of the army engineers in the near future.

The mechanic arts of the coast are extensive and diversified. The machine works, of which there are a great number, employ a large corps of draughtsmen and intelligent designers to prepare what has been ordered to-day and what will be required to-morrow. These are engineering establishments in the full sense of the term, where contracts for work of any kind are entered into irrespective of patterns, drawings, or precedents in the same line. One may order, in any of the principal works, a locomotive, a steamship, the framework of a twelve-story building, a steam plow, or a ton of bridge bolts, and the work will be done. The methods are in many respects advanced, and the versatility of the practice offers a fine field for students and apprentices.

The building of the *Charleston*, *San Francisco*, *Monterey*, and *Oregon* for the United States Navy, the *Peru* and other merchant steamers of a high class, indicate what exists in the line of marine engineering and ship-building. The ponderous plants of the Comstock mines, of which a single pumping engine cost a quarter of a million dollars,

GEO. J. SPECHT.

the wonderful and nowhere-equaled system of urban cable railways, the extensive manufacture of high explosives, and numerous other industrial articles manufactured on a larger or smaller scale, attest that we have a claim for diversity.

Turning now to the learned societies and professions, we find on the Pacific coast a full measure, and a record that needs no explanation here. In geology, astronomy, geography, history, electrical technology, chemistry, and pure science there are the contributions that naturally arise from a cosmopolitan population. From these redundant sources is drawn the membership of the Technical Society; and, coming now to the particular facts of its existence, we can do no better than quote some passages from President Richards's annual address, delivered before the Society on January 7, 1892:

"The Technical Society of the Pacific Coast has not been evolved from a small beginning and a few members, as is common in such cases; but it has, nevertheless, been obliged to follow the inexorable law of evolution, of which the main element is time. The Society was founded in 1884, and the roll signed at the time of its organization contained the names of 61 civil engineers, 30 mechanical engineers, 12 mining engineers, 11 architects, 6 chemists, and 2 patent attorneys; in all, 126 members. This was an extraordinary beginning, not only in respect to the number of charter members, but also in the character and qualifications of those enrolled. It included most of the eminent engineers in San Francisco, and, as an assemblage of people engaged in technical pursuits, could not, perhaps, have been excelled among an equal population in any other part of the United States.

As a result of this the first papers presented and read before the Society were remarkable. They speak for themselves, and I will digress here to say that the value of these papers was reciprocal, and their influence much wider than is commonly supposed. A look through them recently discloses the fact that, in most cases, the papers presented have aided and greatly promoted the interests of those who contributed them. The members who prepared these essays have become distinguished in the branches to which their papers related. Perhaps they were so before, in most cases; but there is a fair inference that the time and pains invested in the work have been well returned.

"The selection of a title for the Society was fortunate and appropriate,—adopted, no doubt, because the membership was to be drawn from not more than one-fortieth part of the population of the whole country, and consequently under circumstances that precluded a division of professions and pursuits, such as can exist in the eastern states and in the populous countries of Europe. This scheme has proved a most fortunate one, because there is, perhaps, no other association of the kind that has worked more harmoniously, and has been more free from all kinds of dissensions, such as might have been apprehended, and which are too common in associations of the kind.

"The Society's history for several years was nearly what inference would assign. The ablest members presented able papers on the subjects with which they were most familiar, and then came a season of apathy. There was no effort to connect the Society's work with the active industries and interests of the community. It was a purely scientific association, such as this bustling utilitarian country is not yet ready for, and will not be for a long time to come. We can cultivate and promote scientific research in this country, and do so to a great extent; but not in the abstract, as it is done in Europe. There the commonwealth is the great fact of a country; here it is the person and his business, and everything, to succeed, must be connected in some way with the active affairs of life, and involve a factor of dollars and cents.

"In respect to the field in which the energy and influence of the Society are to operate, or to which its efforts are particularly directed, it will not be too much to claim that it is peculiar or even anomalous. On this coast the extent of engineering and technical work in proportion to the population is not only vastly more than in other communities of like extent, but is varied in a degree

that has no parallel in any country. These peculiar circumstances arise not only from a diversity that embraces nearly all the industries of our time, but to peculiarities of methods and requirements that arise out of climatic and other physical conditions peculiar to the Pacific coast. I will mention only one for illustration: the harvesting of wheat.

"This operation, which in most countries is no more than a farmer's problem supplemented by ordinary manufacturing skill, becomes here, in California, an engineering one involving peculiar machinery, immensely greater in size and power than is employed elsewhere, also with very different functions. The wheat is cut, threshed, and put into sacks at one operation and by one machine, requiring as many as 24 horses or equivalent steam power to propel it. From 1000 to 1500 bushels are thus cut, cleaned, and put into sacks in a day by one machine, requiring at most the labor of but five men, and is done by contract at a cost of not more than *one cent a bushel.* This is one-fifth as much as the same operation costs in the eastern states, and is only a tenth as much as in India, where the rate of wages is only one-fifteenth as much as in California.

"Ten years ago the steam engines brought here for threshing failed to meet the requirements, and their manufacture was commenced in a number of different works in this state. Instead of 10- and 12-horse-power engines, 40-horse-power came into use. The furnaces and boilers were made for burning straw on new methods, and the industry expanded to large proportions. Later on the 'combined' machines came into use, performing, as before explained, all the operations at one time, and just now the effort is being made not only to drive the threshing part of these machines by steam power, but to propel them as well.

"If space permitted, it would be a pleasure to extend these remarks to various other technical pursuits: the production of high-grade scientific and mathematical instruments, the thorough laboratory practice, and other branches which our diversified membership embraces.

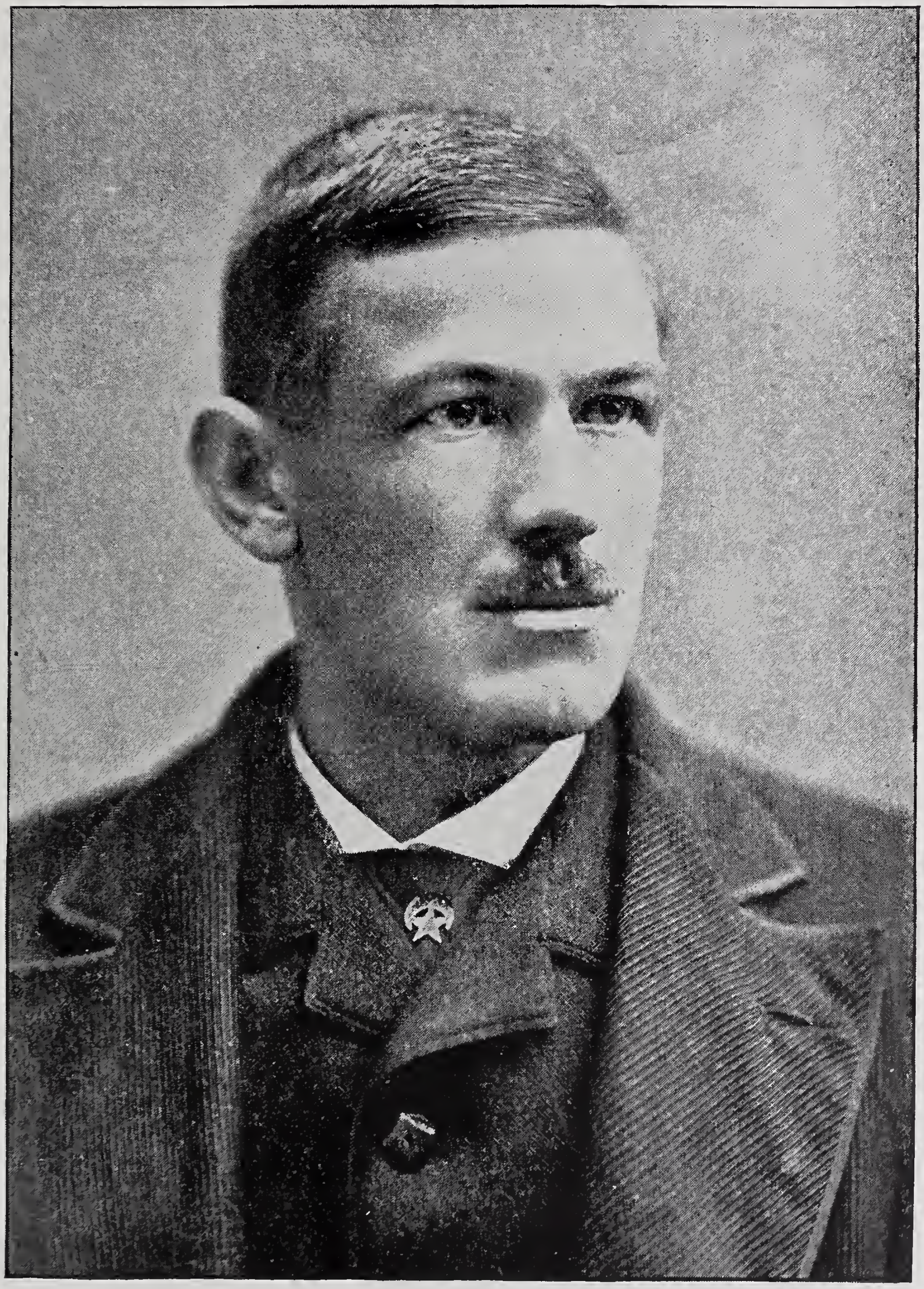
"In conclusion, it will be proper to revert to the fountain-head, so to speak: the teachers, on whom depends the membership of this Society when our day is past,—the faculties of our technical colleges. They have to a great extent aided and promoted this Society by contributions, counsel, and membership. To them we stand much indebted.

"In the wide and bewildering field which has barely been hinted at our Society must dig and delve after new truths, each member contributing his part; and here let me say that his part may be a very useful one if he does no more than come to hear and aid us with his presence. The courtesy that has marked the proceedings of the Technical Society is such that no one need fear a respectful hearing of what he has to present or say, and it is hoped in the term of 1892 there will be a wider participation in the proceedings by all, and especially the new members."

The Technical Society at the present time consists of 219 members, 4 juniors, and 17 associates, distributed among various technical professions as follows:

Architects 4, chemists 4, civil engineers 100, draughtsmen 7, electrical engineers 4, instrument makers 2, marine engineer 1, mechanical engineers 58, military engineers 3, mining engineers 20, naval architect 1, professors 6, scientists 4, surveyors 8, technologists 1, associates of various callings 17.

Of these, 143 are resident and 97 non-resident members, the latter being scattered over the various states and territories which are included in the term Pacific coast; and, although they may but seldom have an opportunity to attend a meeting, they nevertheless take a very active interest in the affairs of the Society, and furnish a very important contingent to its membership. Since the objects of the organization are the professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of the technical profession in all its branches, and the establishment of a central point of reference and union for its members, there are many lines of mutual benefit that tend to hold together a professional fellow-



OTTO VON GELDERN.

ship, though distributed over a very great area of country.

The Society is governed by a board of five directors, of whom the president is the chairman. From this board the executive committee is selected, which, with the secretary, manage the business affairs, except in matters of finance, for which there is also a committee of three, taken from the board of directors. The officers are elected by ballot each year, and, excepting the president and secretary, seldom act but for one term, a provision that calls into the board of management new energy and ideas. The directors are so chosen as to admit of a representation in the board from each of the principal branches of the technical professions.

Regular meetings are held on the first Friday evening of each month, on which occasion papers of a technical character are read and discussed. These discussions are a most essential part of the proceedings, and add greatly to the value of the subject presented. They are recorded by a stenographer, and published with the transactions. Special committees of three, especially skilled, are appointed to investigate upon any prominent work in progress on the Pacific coast or elsewhere, and similar investigations are made into new works and inventions that have general interest or value.

Bulletins of the transactions and proceedings have been issued at regular intervals, and since the beginning of 1892 this has been done at the end of each month. They are made up in a very complete and attractive form, illustrated with clear and artistic engravings wherever the text requires illustration, and make most valuable books of reference. They may be purchased from 1884 to 1891, complete in two bound volumes, for $10.

The most celebrated feature of the Society's work, aside from its great diversity, is the unusual harmony of its conduct and the good feeling engendered among its members. This account of it would be incomplete without reference to this fact, although it has already been alluded to in the annual address of President Richards, above quoted from. This is the main secret of the association's progress and stability. All have great hopes for the future, and if the recent progress goes on unabated there is every reason to believe that the Technical Society will become a factor in California whose influence will be felt in all the engineering enterprises of this country, and that by its advice the commercial interests of the Pacific coast will, in a measure, be guided and properly advanced. The necessity for such an active organization is obvious, and as the Society prospers and gains in numbers its standing in the community and its opinions will grow in importance and popular value. Such a future existence of usefulness was the ideal held in view by the founders of the organization, and in that direction every effort has been made by those who have had the management of its affairs in hand.

One of the most active of its organizers was the first vice-president of the Society, the late George J. Specht, C.E., who gave a great deal of his time and attention, in the most unselfish way, to further the prosperity of the association. It was a most unfortunate occurrence for the organization when he died in 1888, at a time when the first enthusiasm of the members had somewhat cooled, and when it required a self-sacrificing energy to continue and carry on the work against the odds of a general apathy. And this seems a fit opportunity to refer to our lamented fellow-member, whose portrait we have added herewith, in memory of the man who had identified himself so thoroughly with the early history of the Society. He was born in Holstein, Germany, in 1851, and graduated at the gymnasium of that place. After serving with the German army and participating in the Franco-Prussian war, he began his studies in civil engineering, graduating at the polytechnic school of Graz in 1874. His professional practice was had on the Austrian railways, having been connected with the Crown Prince Rudolph railway in 1875, and with the Gotthard railway in Switzerland until February, 1877, when he came to California. On the Pacific coast he entered private practice, having located at San

Francisco, and soon became prominently connected with a number of engineering works. While assistant in charge of the San Diego drainage system in Southern California, during a spell of exceedingly warm weather, he was afflicted with the malady which caused his death. The Technical Society, in mourning the loss of this able man and prominent member, speaks of him in the following words, which are on record :

"We are especially indebted to our lamented colleague as the principal promoter and founder of our institution. He was of an enthusiastic temperament, and had the magnetic power of transmitting it to others ; and, owing mainly to his energy and perseverance, it was possible to gather together the scattered elements that in a new and busy country are so difficult to join in a social pursuit. His services have been most valuable, and we all remember with pleasure his directness of purpose, absolute integrity, and the unselfishness with which he discharged the duties confided to him. Besides his practical work as an engineer, he always endeavored to inform himself of the progress made in the several engineering branches, both on this continent and in Europe, and contributed several valuable papers to our Society and to scientific journals of America and Europe, making much advance in the engineering science known."

His death was certainly an irreparable loss to the association. But his memory is still cherished and held most dear, the work of the Technical Society and its mission having been taken up as an inheritance from the man who had labored so faithfully in shaping a course to be pursued, but who had to leave his task undone and submit it to the hands of others.

Prominent among the members are the past officers of the Society, who have contributed cheerfully to its welfare. Of these we may mention Colonel George H. Mendell, corps of engineers, United States Army, the first president; Charles G. Yale, the first secretary ; Marsden Manson, past president ; and many others who have served it faithfully in various offices that the Society bestowed upon them.

But the most energetic of members, to whose activity and earnestness of purpose the recent remarkable progress of the Technical Society is almost entirely due, is John Richards, a mechanical engineer of wide reputation and unusual skill, who has been its president since the beginning of the year 1890. He is the most zealous in every way, not only in the management of the affairs of the organization and in his prescribed duties as president, but also in his individual contact with members, in his advice in matters of mechanical engineering, and in his literary contributions to the Society's publications. A number of papers testify not only to his ability as a writer and to his mechanical knowledge, but to his ever-ready hand to promote the interests of all.

One of the most interesting papers and perhaps the most valuable that the Society possesses is his "Abrasive Processes in the Mechanic Arts," published in the transactions of 1891, which, in its conciseness and clearness of language and the interesting manner of imparting valuable information of which so little is generally known may be justly called classic. This paper was widely circulated and read with unusual interest. Mr. Richards is a consulting engineer in private practice in San Francisco, and editor of the well-known magazine, *Industries*, devoted to science, engineering, and the mechanic arts. In him the Society has found its truest friend and supporter, and this article would not be complete without referring to him and acknowledging the great debt which is his due, and adding the hope that he may long continue to give his support and advice to the members of the organization.

LUTHER WAGONER.

ELECTRIC WELDED PROJECTILES.*

By Hiram Percy Maxim.

ELECTRICIANS, ordnance experts and military men generally have lately been much interested in a new method of making projectiles. This is the electric-welding process used by the American Projectile Company, Lynn, Mass. and from the success so far achieved it certainly seems that an important step in advance has been made in the manufacture of steel shell.

The American Projectile Company was organized a little more than a year ago to engage in the practical manufacture of all kinds of projectiles, and having been given contracts by both the navy and army, have, since that time, equipped their shops with the necessary special plant, and are now, after a great deal of experimental work, manufacturing on a regular business basis.

All ordnance experts well know the tedious and difficult process at present used in producing the different kinds of forged-steel projectiles. Steel castings for this purpose having long since been abandoned on account of the difficulty in obtaining the desired results and the expense of the castings themselves, it has been, up to the present time, a question of high-grade and expensive armor-piercing projectiles and ordinary cast-iron ones for common use. It has been rendered possible, by the invention of electric welding, and is now one of the aims of the American Projectile Company, to produce a forged-steel shell at about the same price as it now costs to manufacture the common cast-iron projectile. This is accomplished in the following manner:

1. Hollow steel blooms are cast, and from them is rolled out a thick-walled tube having the approximate finished dimensions of the body of the shell. This is then cut into suitable lengths, and to the short blanks thus made are joined, by electric welding, the head and base of the projectile, which have been previously formed in suitable dies. After this is done, the only machining necessary is turning to gage on the outside, cutting the rotating band-score and the fuse thread and seat. This projectile is afterwards hardened, and thus is produced in this very cheap manner a thoroughly efficient wrought-steel shell. It will be understood that this is not the high-grade armor-piercing shell, but a shell that can be used very efficiently against armor of moderate thickness, and will in other respects fulfill the offices of the common shell, at the same time costing no more than the cast-iron now in use. This, of course, is a very important feature, as it will enable the government, without any additional cost, to fill the magazines with this much better grade of shell, which may, in time of peace, be used for target practice, etc., and still be on hand for efficient service in case of war. The company are now filling two large contracts for the navy for shell of this character,—one for 30-pound projectiles for the 4-inch rapid-fire gun, and the other for 6-inch common shell.

Fig. 1 illustrates the formation of this projectile, although in this illustration the midships section of tubing should be longer and the head and base pieces proportionately short. To understand the simplicity of the welding operation, it must be understood that it is only necessary to place these three pieces in contact, one above the other, in an electric-welding machine designed for the purpose, and by means of the electric

* Paper published in "Proceedings of the United States Naval Institute," Vol. XVIII, No. 2, 1892.

current, which is passed from one pole to the other through the joint which is to be made, the metal at this point is quickly heated to a welding heat, and being kept in close contact by mechanical pressure, so unites at this point as to become homogeneous and equally strong with the rest of the metal. The surplus metal, or burr, formed by the pressure is mainly forced upwards, and is removed in the operation of trueing the body of the shell. The operation of electric welding is so simple that it requires no expert to operate the machine, as any intelligent man can be taught in a very short time all that is necessary to produce a weld impossible in any other way. Furthermore, it is feasible to weld the highest carbon steels, steels that are absolutely unweldable by any other process, one to another, or to weld a high carbon to a low-grade steel, or even to wrought iron. The importance of this in projectile manufacture will be understood when it is seen that the head of a projectile may be made of high-grade, expensive steel, and as much of the balance as desired of cheaper, softer material. One who understands the difficulties of obtaining a perfect weld when the metal has to be heated in the blacksmith's fire will fully appreciate the great advantage obtained by this method, where the metal stands fully exposed to view in the open air and comes in contact with no impurities whatever, where the heat can be checked at any desired moment by the simple movement of a lever, and regulated as easily as the turning off or on of steam or air pressure.

These remarks apply to the ordinary operations of welding, but of course there are many forms which are practically impossible to the smith, and among them the tubular sections used in the manufacture of projectiles. The following will illustrate the strength of a weld of high-carbon steel :

A 6-pounder armor-piercing shell, fired at a recent test, slapped or "key-holed" slightly on striking the plate. It, however, passed through a 4-inch iron plate whole. and when recovered it was found to be slightly bent directly at the region of the weld. The snap, as the shell straightened itself in the plate, had been so great that the square head of a brass plug, which was screwed into the fuse-hole, had actually been broken short off by the blow, leaving the threaded portion in the hole. Of course, this great strain, as shown by the bend, came directly on the section in which the weld was located, and this showed not the slightest sign of fracture.

FIG. 1.

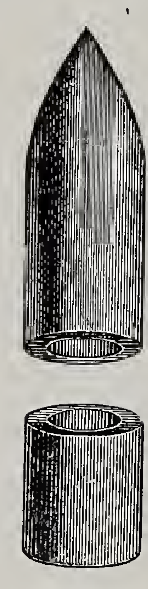


FIG. 2.

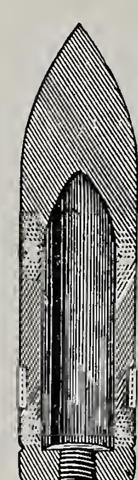


FIG. 3.

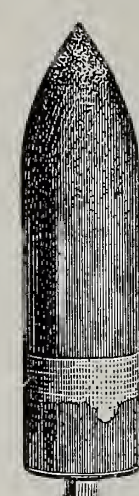


FIG. 4.

The armor-piercing projectiles of this size are being manufactured in two pieces, as shown in Fig. 2, and in section in Fig. 3. In this case no tubing is used. Fig. 4 shows one of these projectiles that has been fired through a

4-inch armor-plate. One of the marked peculiarities of these armor-piercing projectiles is the following:

The head section is hardened uniformly all over; the base section is not hardened at all. When the two pieces are joined by the electric welding, one of the features of which is limiting the heat to a short distance on either side of the joint, the shell is placed with a portion of the head in cold water, and thus the heat from the weld draws the temper gradually toward the point, thus leaving the base unhardened, and from it tapering to the necessary hardness at the point. Aside from this simple method of drawing the temper gradually toward the point, it will be seen that the hardening of the head alone is a very much less difficult operation than heating and hardening the whole projectile; also that temper-cracks and other defects may be very easily distinguished in this portion of the shell before the base is welded in. This is considered one of the very important features covered by the patents of this company.

Another style of projectile now being manufactured is the shrapnel, for the army 3.2-inch field-piece, illustrated in section in Fig. 5 and in detail in Figs. 6, 7, 8, 9, and 10,—Fig. 6 being the head forging, Fig. 7 the tubular midships section, Fig. 8 the steel diaphragm and central tube, forming, respectively, the powder-chamber and the passage from the point fuse to it, Fig. 9 the base forging, showing the shoulder on which the diaphragm rests, and Fig. 10 the copper rotating band, which is afterwards shown pressed on the shell in Fig. 5. The method of making this shrapnel is as follows:

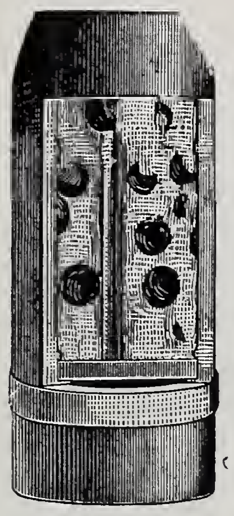


FIG. 5.

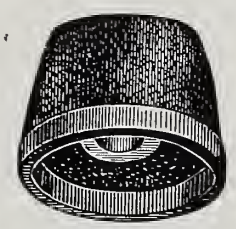


FIG. 6.

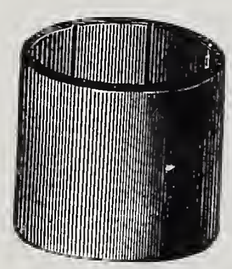


FIG. 7.

FIG. 8.

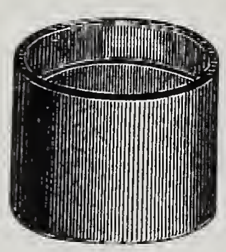


FIG. 9.

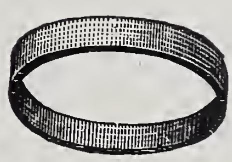


FIG. 10.

The base piece and tube, Figs. 9 and 7, are placed in contact in the welding machine and joined together, forming a deep cup; while the weld is still hot, the diaphragm and tube are dropped into it so that the former rests on the shoulder of the powder-

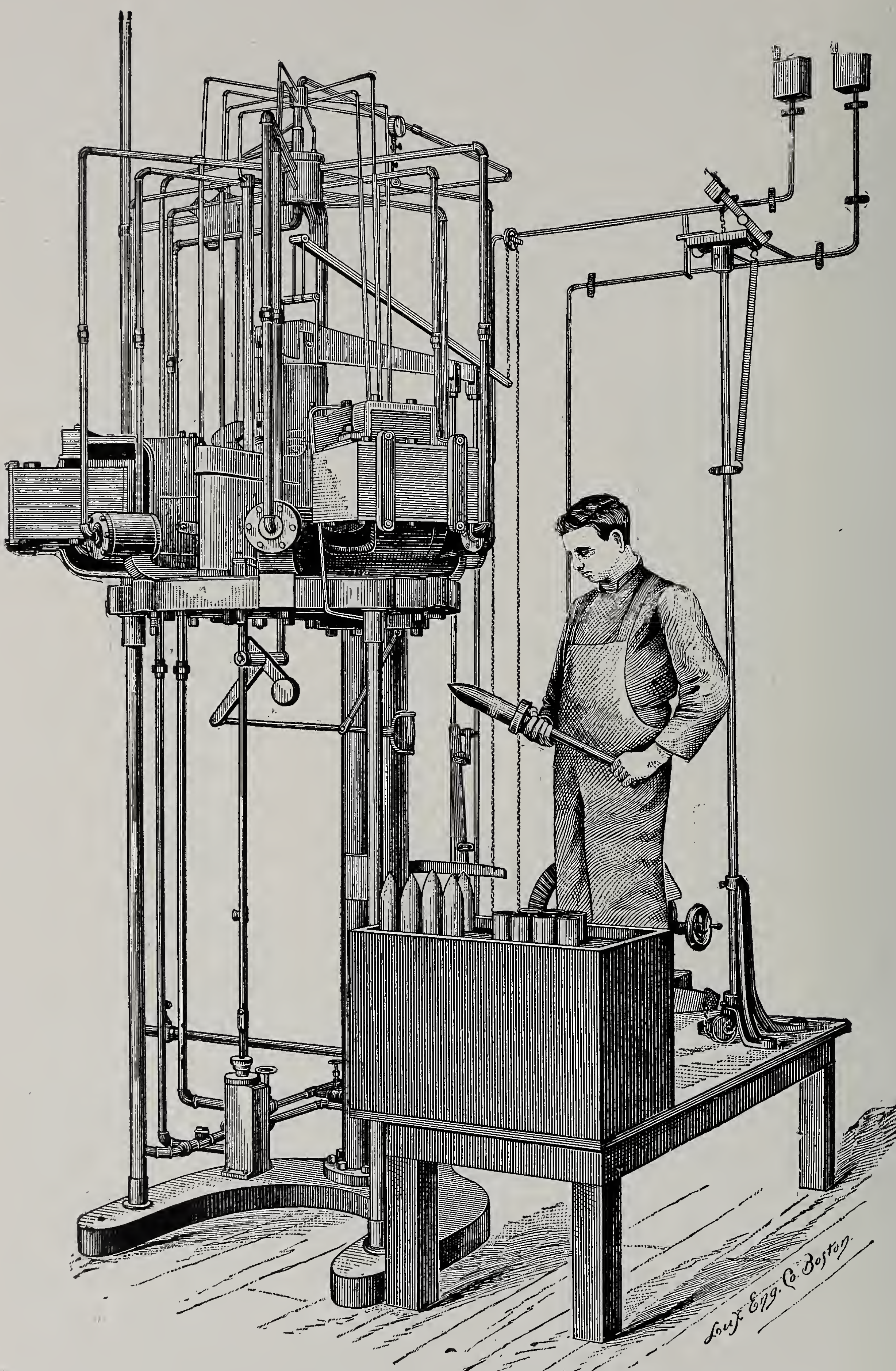
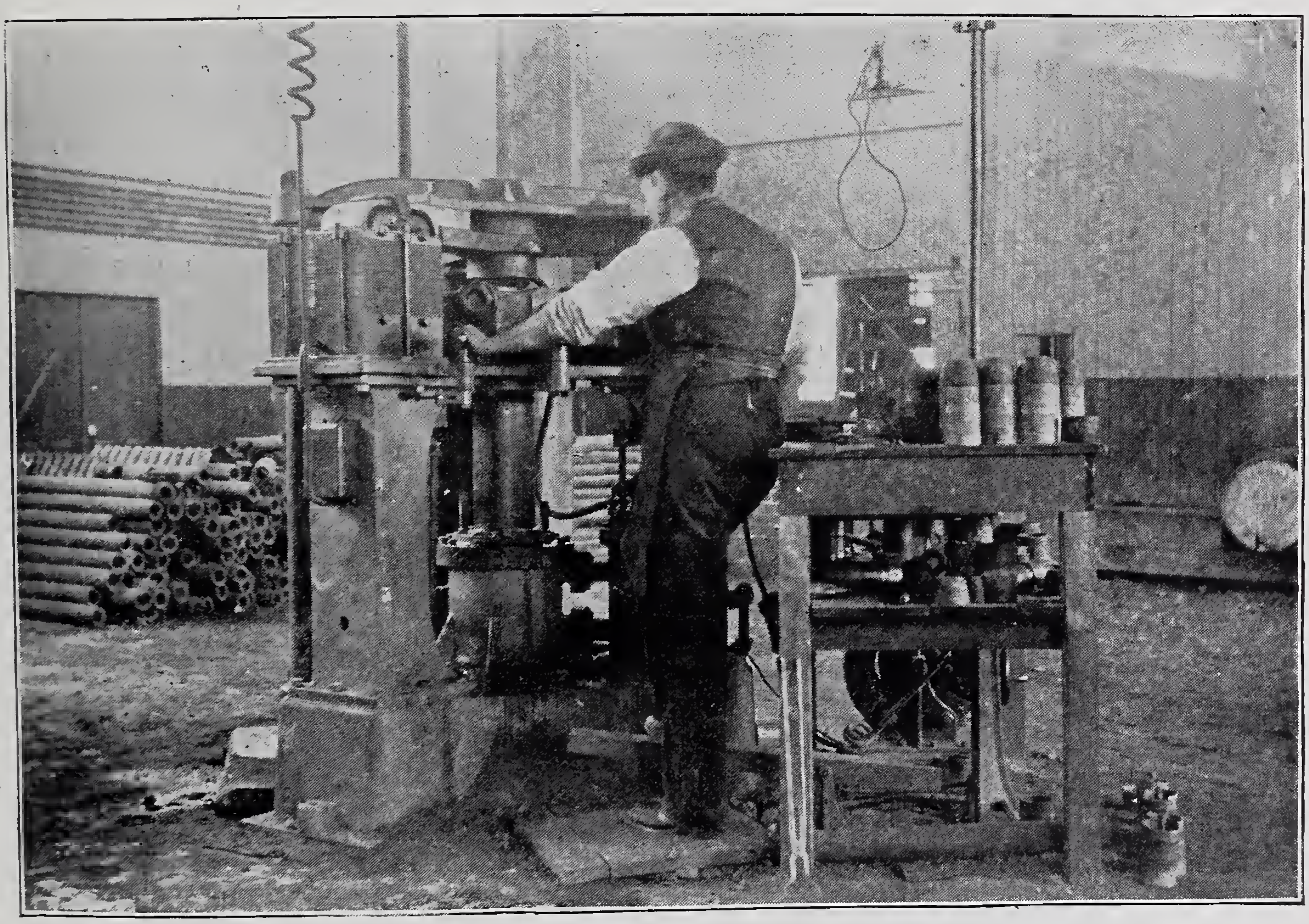


FIG. II. ELECTRIC WELDING MACHINE FOR SMALL PROJECTILES.

chamber. The weld is then lightly swaged, thus locating the diaphragm firmly in place. Next the head forging is placed in contact with the open end of the tube and with the small central tube passing into the fuse-hole. This is then similarly joined by an electric weld. Afterwards the upper end of the small tube is crimped over a slight shoulder in the bottom of the fuse-hole. The outside of the shrapnel is then turned to gage. A small hole is drilled in the head, communicating with the interior cavity; through this the shrapnel is filled with the necessary bullets; next the matrix is poured in, and finally the hole is closed by a small plug which is screwed into place. Before the case is filled with the bullets and matrix it is hardened to give increased rigidity to the thin walls and to increase the number of fragments into which the case will burst. In trial, these shrapnel have given most excellent results.

So far, the largest shell being manufactured by the American Projectile Company are the 6-inch naval common shell above referred to. These weigh, empty, 94 pounds, and having an outside diameter of 5.96 inches, with a thickness of wall of 0.95 of an inch. It is expected, in the near future, that the company will undertake the manufacture of very much larger projectiles, as the only limit seems to be the possibility of obtaining the necessary tube, and arrangements are now being made to have this produced of the necessary dimensions to make as large as 12-inch shell.



It is believed that projectiles of the character described in the beginning of this article will be peculiarly adapted for use in mortar service against deck armor, etc., as they will have all the advantages of armor-piercing projectiles for penetrating that thickness of armor, and can be produced at a fraction of the cost of the more expensive missiles.

In conclusion, a brief description of one of the welding machines may be interesting. Fig. 11 shows one devoted to small-size projectiles, such as the 6-

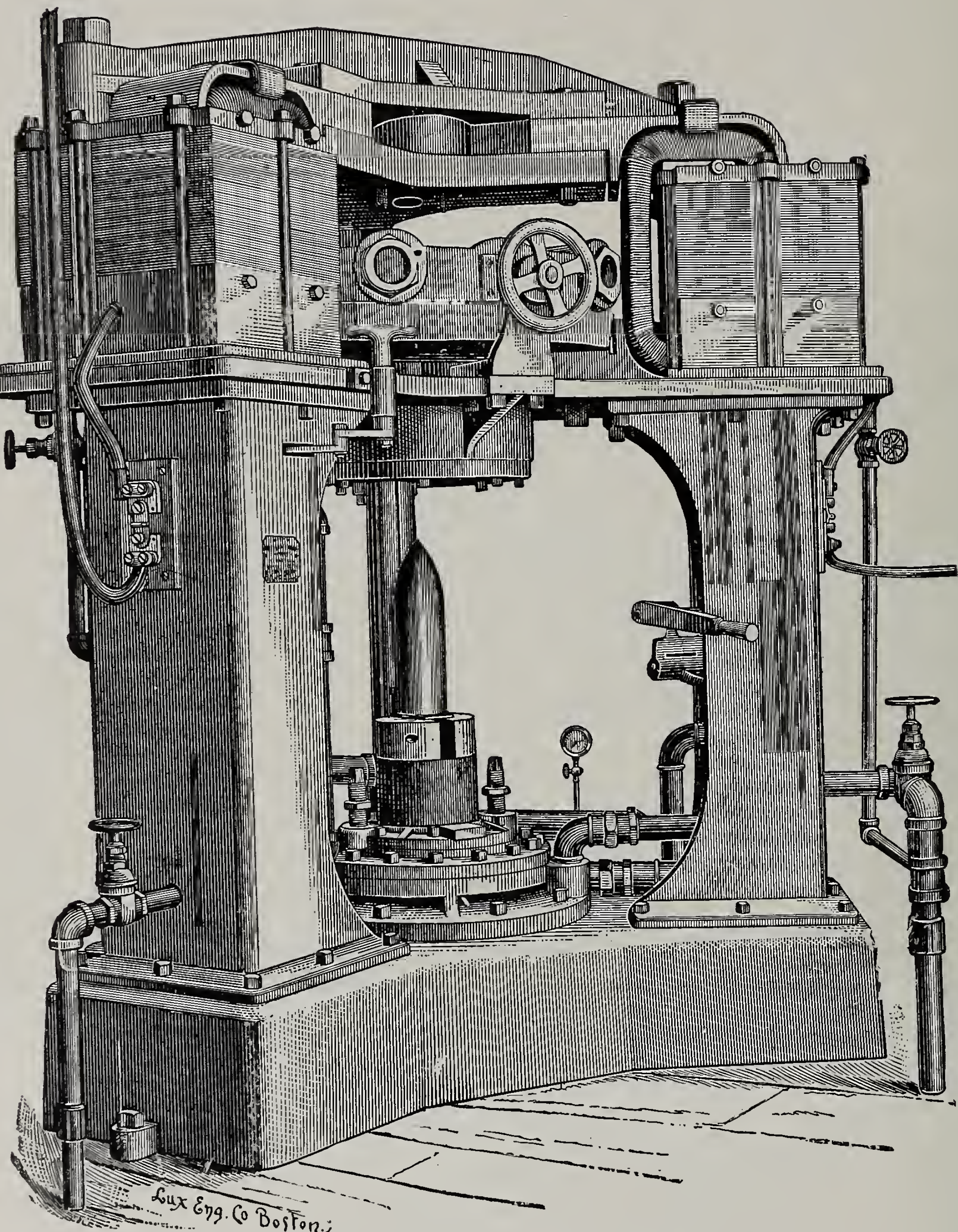
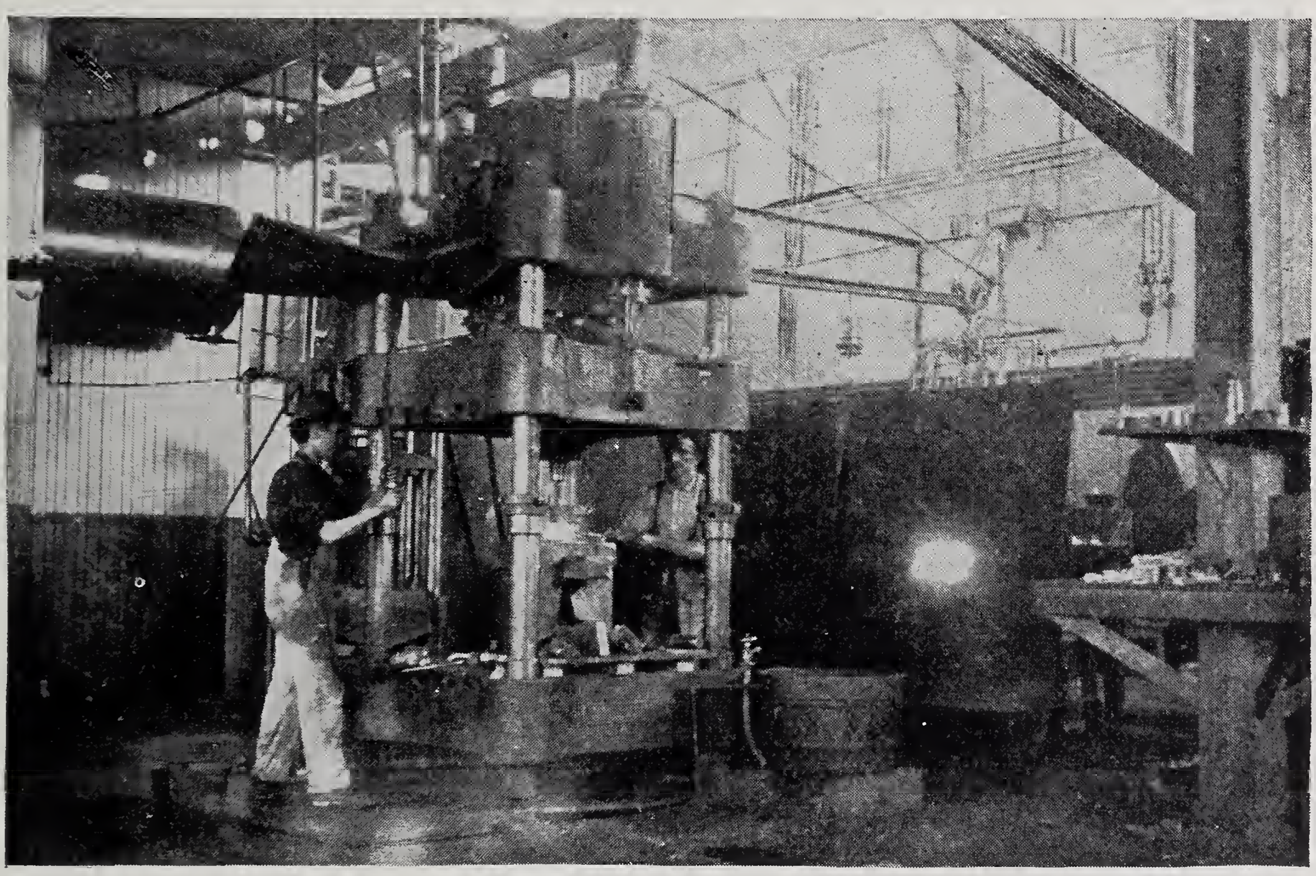


FIG. 12. ELECTRIC WELDING MACHINE FOR LARGE WORK.

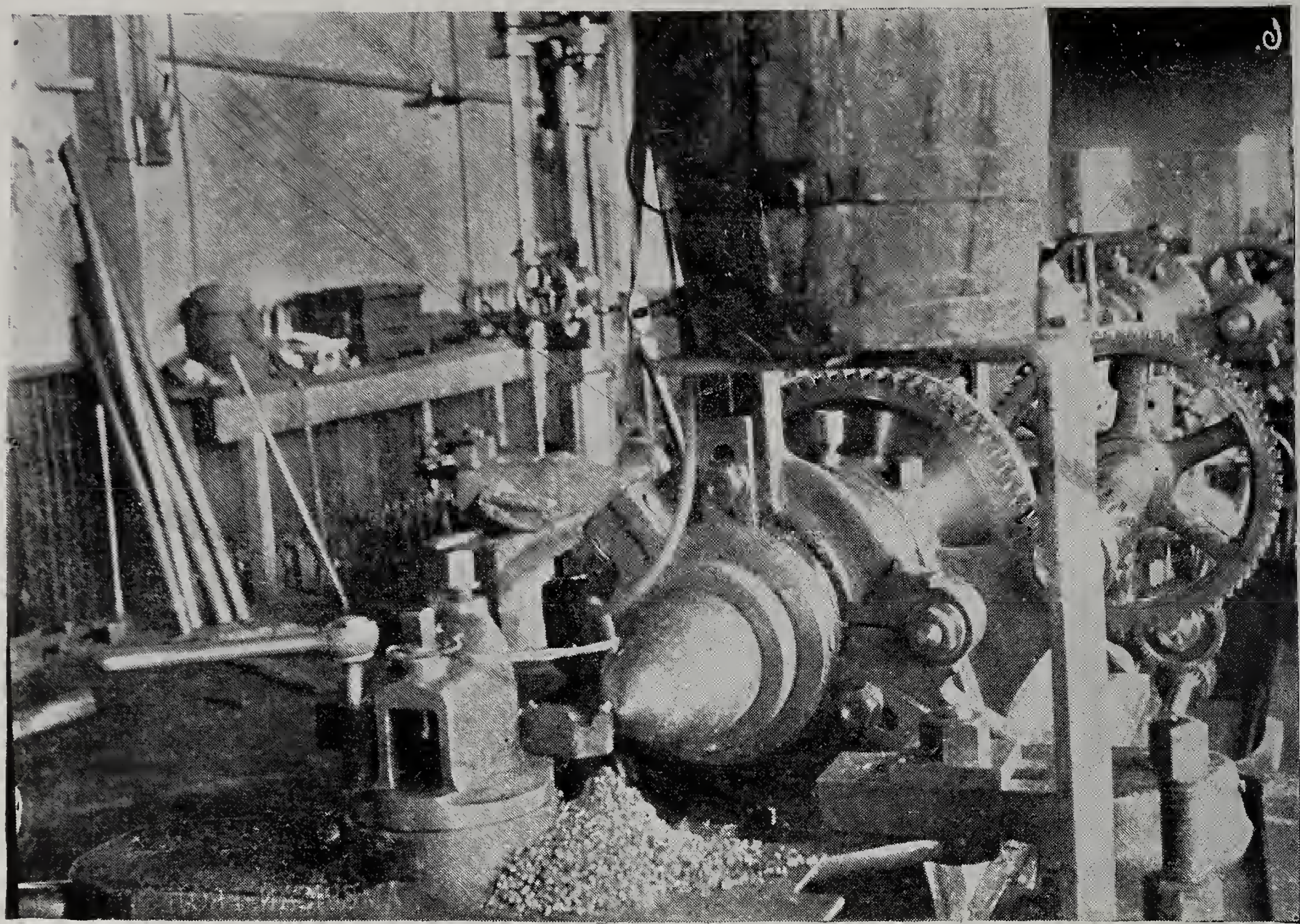
pounder armor-piercing and common shell. It stands high from the ground to enable the operator's helper to place and remove the shell being operated on from beneath. After placing the separate pieces of the shell in the machine from the under side, a movement of the hand-lever in front of the operator throws in a set of hydraulic contacts through which the electric current passes to the portions of the shell they enclose. This current is obtained by transforming the primary current of 200 volts and about 250 amperes into a current of one-half a volt, and consequently enormous quantity. The current is perfectly controlled by a switch, operated by a foot-lever and in connection with a reactive coil. To carry this great current, heavy copper castings are necessary, which are kept cool by water-jackets and a continuous circulation of water. These water connections, for cooling and for pressure purposes, are shown by the numbers of pipes and tubes at the top of the machine. To give the necessary pressing together when the shell is at the welding heat, another hydraulic cylinder is provided. This is controlled by a lever conveniently placed. After the weld is finished, the assistant quickly carries the shell to a small hammer, where the burr is lightly swaged. It is then placed, head downward, in a shallow vat, to keep the temper from drawing out of the point.

The general construction of all the welding machines is extremely simple, the only thing requiring any particular care being to insure proper electrical contacts on the shell. This cut is taken from a photograph, and shows the operator holding the freshly welded shell on its jig. This will give an idea of the local limit of the heat after the weld has been made.



ELECTRIC WELDER USED ON SHRAPNEL SHELL.

In welding large projectiles, another style of machine is used. This is illustrated by Fig. 12. In this case the parts to be welded are placed upon the head of a hydraulic ram, which moves them upward into position as shown. The electric connection in this case is also made by hydraulic plungers in elec-



FINISHING A PROJECTILE.

trical connection with the induction coils, and they are caused to move in or out by means of a valve operated by the T-shaped handle shown near the top. A foot-lever actuates the switch, as in the smaller welding machine, and a hand-lever shown on the right of the machine controls the upward pressure. The work at present being done by this machine is a section of eight square inches per weld, the operation being completed in 3½ minutes.

In describing the tubular shell of the 4-inch type it should have been stated that these projectiles have already been successfully tried against thin armor and have exceeded in results what was expected of them.

A great number of special machines and appliances necessary for making this business a practical and financial success have been designed by Lieutenant William Maxwell Wood, U. S. N., who is also the inventor of this system of manufacturing projectiles.

MOTIVE POWER FOR STREET RAILWAYS.*

By Alfred F. Sears, Mem. Am. Soc. C. E.

IT is part of the experience of every civil engineer who has had to deal with the problem of traction for urban lines that, as yet, no satisfactory solution has been presented. In every system thus far popularized by use on street railways there is a vast waste of power in transmission or transformation, or in hauling cumbersome loads of fuel and water. It has lately become the duty of the writer, in the interest of a street railroad company, to investigate with patient care the subject of motive power for such works. The problem has been: What is the most economical motive power for street railroad traffic; and what is the cheapest application of that power compatible with the conditions demanded by the preferences and prejudices of the public in cities, whether as residents subject to its presence, or as habitual patrons using the system as a means of locomotion? In studying the matter, he has been impressed with the belief that a collation of the data used, together with the conclusions reached, in as brief form as consistent with its clear elucidation, will be of value to the profession; also that a discussion of these conclusions by members of the society will serve to either confirm the deduction or reveal a more correct solution, so that in any event the general good will be advanced by offering this paper to their attention.

There should be no difficulty in recognizing a primary fact,—viz., that no system of motor suitable to all circumstances has yet been devised, and probably never will be. It is a generally accepted doctrine that steam and its derivatives, electricity, and compressed air, are invariably cheaper than animal power. It is indeed difficult to imagine a situation where the opposite holds true. And yet, in the republic of Mexico, a railroad, highly finished in every detail of road-bed, masonry, and superstructure, carries mail, passengers, and baggage from Esperanza, on the Mexico and Vera Cruz line, to Tehuacan, a distance of 50 miles, in five hours with animal power only. Freighting is, of course, done at a slower pace by the same kind of power. Nor does any other motor seem practicable. There is neither coal, petroleum, nor wood in all that region; while freight charges on the line from Vera Cruz, by which coal might be imported, prohibits the transportation of fuel. On the contrary, provender is abundant and mules are cheap. A similar condition obtains in the City of Mexico and its suburbs, where there is no native fuel, and all urban and suburban lines employ animal power exclusively; and so far as can now be seen, this must remain the condition.

But generally the humanity of man has joined hands with his cupidity, and the civilized world seems bent on finding a substitute for animal power to do its work of transportation. The conclusion reached after a careful, and it is believed unbiased, study is: 1. That steam without transformation is the cheapest power that can be used where fuel can be had for reasonable cost, and is destined to be the street motor of the future. 2. That electricity is the cheapest where it can be produced by water power, and in such cases will remain, as now, a popular motor with passengers and the public. 3. That compressed-air engines will be the cheapest available method and the best for dealing with all the conditions of tunnel and underground lines where electricity is not practicable. 4. That cable roads are best for the steep street sites of hilly towns, and by saving the immense cost

* Paper read before the American Society of Civil Engineers.

of grading are the most economical, if not the only practicable, for controlling the traffic in such situations ; but that they are expensive, inconvenient, and dangerous on level streets in business thoroughfares. These are the conclusions arrived at in seeking a power that shall produce the largest dividend and the quickest return.

Mr. Henry C. Adams, the distinguished statistician of the Interstate Commerce Commission, has inspired and supervised a comparative statement, made directly by Mr. Charles H. Cooley, of the United States Census Bureau, and published in "Census Bulletin No. 55," touching the relative economy of cable, electric, and animal motive power for street railroads. This document is preliminary to another, which is to contain complete statistics of street railroads, but is not yet ready. Bulletin No. 55 embraces statistics of fifty lines of street railroads, ten of which are operated by electricity, ten by cable, and thirty by animal power. We are not told the names of these lines, nor are we given any hint betraying their locality or the price of fuel or provender.

On only one line are all three classes of power availed of, and so uniform are the resulting costs of operating per car mile and per passenger carried that we seem to have met a case of peculiar wisdom in selection, though probably the animal power remaining is a necessity of the problem, to be hereafter improved. Thus the tabulated results are as follows :

Power Used.	Cost per Car per Mile.	Cost per Passenger Carried.
Cable	9.39 cents.	3.48 cents.
Electric	9.77 "	3.75 "
Animal	9.21 "	3.49 "

While the operating expenses appear at first view so nearly equal, a closer inspection betrays but little difference in the work done, for the cable line in 11.69 miles of street contains but 566 feet of 14 per cent. grade, against 475 feet of 5.2 per cent. grade on four miles of the electric line. If we take the average of the 50 roads under consideration, we find no great difference in the average cost of carrying a passenger by any of these three motors over their different lines. Thus the operating expense is :

Per passenger carried by cable railway	3.22 cents.
Per passenger carried by electric railway	3.82 "
Per passenger carried by animal railway	3.67 "

Being only a trifle different from the corresponding items on the line which in its own single limits includes the three classes of power.

A little farther examination demonstrates that the average aggregate cost of carrying a passenger over all three sections of the composite line is almost exactly the same as a similar duty performed on three average sections of the entire cluster of 50 lines, being 10.71 cents in the former case, and 10.72 cents in this,—an absurdity illustrating the fallacy to which the engineer is exposed in the use of averages, and also the comparative worthlessness of the passenger unit in calculations of this class for the United States, where the distribution of population is a factor so constantly changing in amount and direction that no prediction or estimate of it can be made with a fair degree of certainty.

The car mile unit seems to be the correct representative of work done on a line. The car must be moved whether full or empty, and the difference of duty on electric and animal roads between a full car and a car but half full is not appreciable in the cost of operating, since, in both cases, the driver will make up expenditure of power in speed when his lighter load will permit. This is not practicable with the cable lines, where the velocity of the car is uniform and is that of the cable. When steam, however, is directly applied, as in locomotives and dummies, the expenditure may be more exactly proportioned to the load. This advantage will also accompany the compressed-air motor, and perhaps the storage battery of the electric systems. Examining the car mile cost of operating the 50 lines under consideration, we have :

Kind of Power.	Length of Line.	Number of Cars.	Cost per Car per Mile Run.
Cable	143 miles.	583	14.12
Electric	67 "	78	13.21
Animal	550 "	1500	18.16

These figures, again, are averages, and in the case of the ten cable roads cover limits extending from 9.4 cents to 22 cents ; in the ten electric lines the figures range from 8.34 to 23 cents ; and in the animal lines from 9.1 to 27 cents, —another illustration of the fallacy of averages, which may be made still more apparent from the figures of these tables, for from the 30 animal lines it is possible to select 10 of which the average cost per car mile is 10.82 cents between limits varying only from 9.1 to 13.89 cents. An important difference in the operating expenses appears in the item, "repairs of road-bed and track," and for obvious reasons. Thus it cost $709 per mile of track to keep the cable roads in shape a year, while the same item for the electric lines amounts to $190, and for the animal lines $430. But in this connection we must bear in mind that the animal lines moved 1500 cars, to only 78 and 580 moved by the electric and cable lines respectively.

From figures obtained by the Census Bureau and published in the *Street Railway Review* of January, 1892, it appears that, up to the date of compilation, the operating expenses of lines in the United States had been as follows :

Kind of Power.	Operating Expenses per cent. of Earnings.	Dividends on Stock, per cent.	Surplus Capital on Hand, per cent. of Capital Stock.
Cable	67.7	10.15	11.7
Electric	70.4	5.59	2.5
Animal	73.7	7.03	10.5
Steam	57.3	6.03	5.2

It is proper to observe at this point that cable roads are built only where the heaviest traffic is already assured, while the steam motor in its various forms has been confined thus far to the most sparsely peopled regions demanding street railway accommodation, and is almost limited to southern and western states, where are found 351 steam motors out of a total of 391 in the United States.

Formulating the results given by the "Census Bulletin No. 55," and calling the cost of animal power 100, the cost of cable will be 77.74, and of electricity 72.74. In 1889 Captain Eugene Griffin, U. S. Engineers, arrived at a different result, for, calling the maintenance of animal power 100, he demonstrated the cost of cable traction to be 79.5, and of electricity 46.5. At about the same time Mr. F. H. Whipple, in a book on electric railways, determined that, if the cost of animal power be designated at 100, then cable traction would stand at 118, and electricity (overhead wire) at 83. It would appear that these figures were reached by accepting as accomplished facts the promises of the electrical enthusiasts, who (and it is said feelingly) had already acquired the noble art of making hay while the sun shone.

Suppose we formulate in the same way the latest data giving the proportion of operating expenses to the earnings of all or nearly all the roads in the United States, as taken from the *Street Railway Review*. We shall then have the proportional cost of power as follows:

Animal lines which spent $73\frac{7}{10}$ per cent. of their earnings, say	100
Electric lines which spent $70\frac{4}{10}$ per cent. of their earnings, say	$99\frac{5}{10}$
Cable lines which spent $65\frac{7}{10}$ per cent. of their earnings, say	$89\frac{1}{10}$
Steam lines which spent $57\frac{3}{10}$ per cent. of their earnings, say	$77\frac{8}{10}$

There seems but little reason to doubt that if steam could be inoffensively applied, it is the proper substitute for animal power on the streets of cities.

In the cable road there is a vast expenditure of power exhausted before any useful load is moved. In the ten cable roads of the bulletin the average length of track, which is also the length of the cable, is more than 14 miles, and the power must drag a load that weighs from 60 to 80 tons, to be moved six miles per hour, before any paying duty is performed. The work done to keep this mass in motion may be imagined when we observe the cost of repairing cables and pulleys, which for these 10

lines of 143 miles amounted to $283,338 in a single year, or $1981 per mile in that time.

The electric system wastes in losses a very important percentage of the steam-generating power. How much it is not possible to say without raising the hue and cry of contradiction. Personal observation leads the writer to believe that the traffic which feels 50 per cent. of the steam power generated at the central station has extraordinary luck in its successful economy. With the steam locomotive, whether disguised in the dummy or otherwise, there is loss in carrying the load of fuel and cold water, as also in the vehicle or magazine which contains them.

After careful investigation among a tiresome mass of inventions, some of which show much ingenuity, there have been found two systems which seem to promise, in one form or the other, and perhaps in both, the street motive power of the future. They are, in one case, engines moved by compressed air, and the other by compressed steam, or water of such a temperature and under such pressure that, when released, it becomes steam, ready for work. The motors for urban use may in both cases be called small packages of condensed power. An advantage of both engines will consist in the fact that they can be built to do a fixed maximum of duty of defined limit, and that this limit is so restricted as to prohibit an attempt to accomplish too much. Thus the compressed-air engine, once charged, is good for a distance of 10 miles without recharging. The compressed-steam motor will go 40 miles without reinforcement.

A Toledo street railway company, after experimenting with the compressed-air motor, is so far satisfied with the results obtained that a complete plant is being installed in that city. Professor D. S. Jacobus, of Hoboken, saw the system in operation at Nantes and Vincennes, France, where the roads are five and seven miles long respectively, and have been successfully operating this system for twelve years. At the New York meeting of the American Institute of Mining Engineers, held in September, 1890, that gentleman read a valuable paper, which has been published by the institute and is the authority for what is here said of the system. As that paper is accessible to the members of this society, is sufficiently illustrated, and is carefully elaborated in details, only the general facts are here given touching its construction, leaving it for those personally interested in the subject to study the minor features in the paper mentioned, or on the ground at Toledo. In the motor car two small engines are connected so as to rotate the front axle of the car, a reversing lever being used to alter the cut-off and change the direction. The compressed air is held in tanks under the bottom of the car, and is admitted to the engine cylinders after passing through a mass of hot water, which leaves the charging station at the temperature of about 300° Fah., and is reduced to 212° when it has returned to that point. The engine cylinders are 5½ x 10¼ inches, and the compressed air is charged in its retorts at about 425 pounds per square inch.

Professor Jacobus estimates the cost of compressed-air motive power, as compared with horse traction in Nantes, where there is experience, and great economy of air is observed in handling the engine, to be such that if the cost of animal power is put at 100, the cost of compressed-air power will be 63.33. He is of opinion that for a time this power must be limited to localities unencumbered with snow, and believes that for underground, mining, and tunnel service its ventilating capacity will make it of great practical value. This system is not only in operation at Nantes and Vincennes; it is also in use at Nagent, near Paris, where each motor draws after it a train of two trailers; at Marseilles, where the cars are operated under a storage pressure of 1200 pounds per square inch; and at Berne, Switzerland.

An interesting and fairly conservative account of the performance of the compressed-air engine at Toledo may be found in the *Chicago Street Railway Review* for January of this year. Snow and cold weather seem not to have troubled the experiment, and the old difficulty of frozen air valves no longer

exists. The manufacturers claim a trip of nine miles' length as the limit of duration of power, and there seems but little chance of increasing this capacity without lengthening the car or raising its floor higher from the street level.

The last mode of applying power to which attention is invited is in the form of compressed steam, and was studied twelve years ago. Later the invention was laid aside for want of means to improve the original excellent idea, and during the past year the tendency to recur to some mode of applying steam directly in the motor has led to such improvement on the original design that a fair ground of hope exists that we have at last the motor best adapted to urban travel, in what is still known as the Angamar motor, now the subject of experiment in Chicago. Several other plans are also now being proved in that city,—viz., the Patton gasoline engine, wherein a portable dynamo is operated by steam, and the product transferred to an electric motor connected by the usual method with the wheels; the Judson compressed-air engine, having three conduit charging stations for each five miles of road; the Belgian motor, which Mr. Yerkes bought in Belgium and has been trying upon one of the North Side roads,—a rather small and somewhat complicated locomotive referred to by the Baldwin Locomotive Works, in their letter following, as being "too small"; the Connolly gas motor which has inadequate power unless unreasonably large for street use; the Prouty motor, a small steam engine with inadequate power. These and indeed several other devices serve to illustrate the variety of invention, all tending in one direction.

When the writer's attention had been called to the Angamar motor, he wrote to the Baldwin Locomotive Works to learn the opinion of men who have probably built more street dummies and very small locomotives than any other factory in the world, of a machine with such pretensions. They replied:

"We believe that such a motor as you describe can be constructed, and that, if satisfactorily developed, a large demand will result. Many roads which are at present operated by electricity, as well as other roads which are unable to obtain electrical franchises and cannot make the expenditure involved by the cable, will be likely to adopt them."

Those gentlemen also said in the same letter:

"The demand for a steam motor is so strong that, notwithstanding the admitted objections to these machines, we have constructed upward of 300 of them.

"During the past winter our attention was strongly drawn to the desirability of designing a condensing motor. We built an 18-ton compound motor, in which we sought to accomplish the following: 1. To utilize the steam by expansion to so low a tension that its escape from the cylinders would be accompanied by little or no noise, and at the same time such expansion would so considerably reduce the temperature of the escaping steam as to render it easier to condense. 2. To provide a condenser large enough to condense all the escaping steam. 3. To rely entirely upon natural draught excepting when unusual power was required, in which case the steam could be diverted from the condenser and discharged in the ordinary manner through the exhaust nozzles into the stack.

"This motor was measurably successful and accomplished the results intended; but we did not succeed in entirely avoiding the show of steam in bad weather. This was probably due in part to the large size of the motor, requiring the generation of so considerable a volume of steam as to render its condensation more difficult. We look for more satisfactory results from a similar experiment with a smaller motor. Meanwhile that motor was purchased for noiseless switching service in Wilmington, N. C., where it is doing satisfactory work.

"Some time since the North Chicago Street Railway Company imported a Belgian motor which is said to accomplish all the results which we sought. We have contracted to duplicate it, and of course guarantee equally satisfactory results. This motor is, however, too small. We have also agreed to build, from our own design, a somewhat more powerful motor, with which we have guaranteed equally satisfactory results."

On the strength of various representations, a series of experiments has been made, at the writer's request, with a motor built by the Kinetic Power Company, in Chicago, having the Angamar boiler, the results of which are here presented. They were obtained from the observations of both interested and disinterested parties, and the writer places such confidence in them that he has recommended the system to his company as the proper and only solu-

tion of the street-motor problem in all ordinary cases.

The Angamar-motor car in size and appearance resembles the grip car of a cable road. As above said, this motor is a contrivance for using compressed steam. Water is heated at a "charging station," so called, to the temperature of 387° Fah. (200 pounds pressure). This station consists simply of furnace and boiler, — preferably the upright tubular,—which should be of comparatively large capacity. A plant of 400 horse-power will be ample for about 100 motors of 50 horse-power each. This stationary boiler is tapped on the low-water line for connection with the retort of the motor, and also in the dome. Water may thus be charged above, or steam, or the two together when it is requisite to quickly produce the maximum pressure in the retort. The latter, with all its connections of pipes, dome, and firebox, is thoroughly jacketed to prevent loss of heat by external radiation. When the retort of the motor has been charged with hot water and steam, a few shovelfuls of burning anthracite coal are thrown into the firebox. The motor now under experiment in Chicago has a pair of 9 x 10 cylinders; the retort, having a capacity of 263 gallons, is charged with 160 to 170 gallons of water, heated, as already said, to nearly 400° Fah., and is rated by indicator test at 43 horse-power.

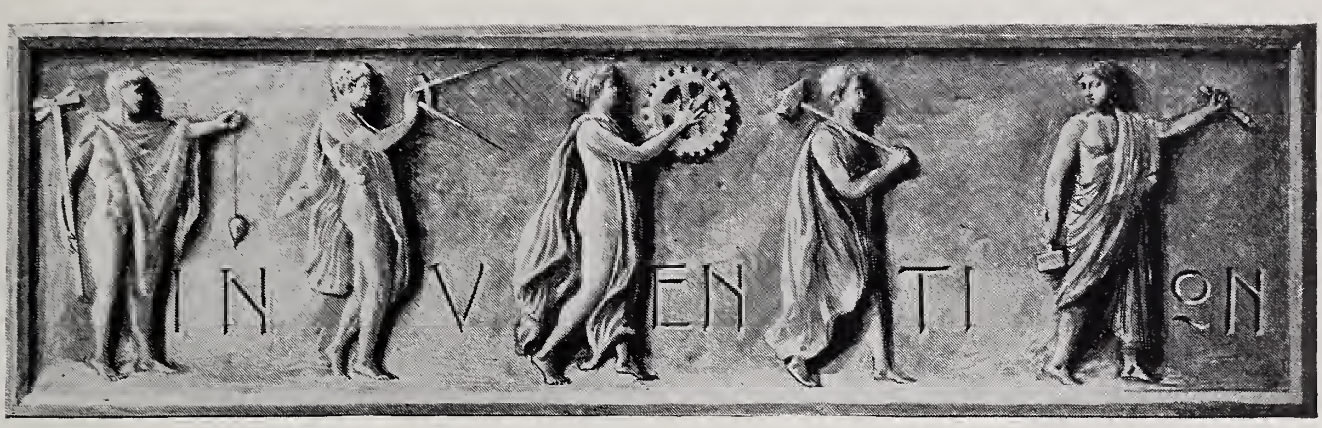
By this system it is seen in experience that, while the quantity of water in the retort is evaporated and the rapidity of steam-making tends to increase, the fuel in the firebox decreases by consumption in amount and heating power, and thus reduces the tendency to excessive pressure. As the highly heated water is conveyed from the charging boiler to the motor it first becomes steam vapor, and as such enters the retort; but as the injection is continued a water level becomes established, showing that a portion of the steam under such pressure has returned to the form of water.

Accounts of trips with this machine now in Chicago have been received in which it is reported to have made 20 miles with one charging on the track of the West Chicago Street Railway Company. The retort for holding water contains 263 gallons, of which about 160 are, at the beginning of the trip, for evaporation. The driving wheels are of 31 inches diameter, and thus 1303 cylinder volumes of steam per mile are used up by each of the two cylinders. Or, the capacity of the cylinders being 636 cubic inches, the volume of steam used per mile will be $636 \times 2 \times 1303 = 1,657,416$ cubic inches.

The 160 gallons of compressed hot water contain an energy of 37,000 cubic inches $\times$ 1642, the capacity for expansion, or 60,754,000 cubic inches of steam. If this value were maintained, the motor has a traveling ability of about 37 miles under the charging above mentioned. The actual experience in a course of eight days shows that it may be relied on, starting with 155 pounds pressure, to make 20 miles without new charging, and return to the shop with a pressure of 142 pounds after such a run, using 30 pounds of anthracite coal in the trip, and carrying 80 passengers on motor and trailer, moving sometimes at 18 miles per hour.

The machine appears easy to manage, and does not require any more intelligence in the driver than the ordinary electric car. It shows no smoke, and where anthracite coal is not to be had it is believed that the simplest arrangement of kerosene burners will maintain the condition of heat required. An improved arrangement has been designed by which condensers are to be added to prevent the slight noise that is now heard in the escaping steam. The weight of a motor car, which, as before stated, is arranged much like the ordinary cable grip car, and like it will haul one or more trailers, is about that of the ordinary electric motor's weight, from five to eight tons.

Captain Charles F. Thomas, the constructing engineer of the Kinetic Power Company, estimates the cost of power alone per car mile at $\frac{55}{100}$ of one cent, which is much less than one-third the cost of electric power on the West End system of Boston.



NOTES ON NEW AND PATENTED INVENTIONS.—I.

By John Richards, President of the Technical Society of the Pacific Coast and Editor of "Industries."

INTRODUCTORY.—It is proposed in the articles that will follow to review various inventions, especially those of a mechanical nature and such as seem to have a general interest or mark an advance in the arts to which they pertain. It is not pretended that the selection made will be complete, or that opinions expressed concerning them will be infallible. The most consummate and versatile knowledge of the industrial arts would not warrant such a pretentious claim. But an effort will be made to be impartial, and to speak without prejudice, fear, or partiality. Any error made in understanding the nature, scope, and purpose of a new invention will be cheerfully corrected by a supplementary notice, when explanation is made and fair grounds presented for such correction. It was at first intended to include in these notices the patents of several foreign countries, but the observations of several years have confirmed the fact that there are but very few inventions, especially those of a mechanical kind, produced abroad that are not also patented in the United States and in England,—if not by the same inventor, at least represented by similar ideas or cases,—so the plan of including Continental patents has been abandoned except in a few cases.

In the great struggle after new methods, processes, and implements that characterizes our day, and which is a principal factor in our material progress, there is a constant rule of the "survival of the fittest." Opposed to this is the claim, sometimes put forward, that the value of a patented invention is not so much in its intrinsic worth as in the method of presenting and introducing it to the world or to a market. Both propositions are in a sense true, but with this qualification: that "permanent" success always depends upon intrinsic worth; and while a short success may be attained by a plausible but faulty invention, the future is sure to relegate it to the place in which it belongs. It is perhaps unnecessary to argue this. Every one's observation will prove it.

Another feature of new inventions that may be mentioned here, and one that will be watched in these notes as closely as possible, is cases where constructive and operative conditions violate the settled rules of common practice or sanctioned practice. To illustrate what is meant, conical shells for machine bearings, ball bearings for other than special purposes, radial running faces as in rotary engines and pumps, and many other things of the kind, condemned alike by theory and experience, are often elements of new inventions. The inventor of a new process or implement, unless himself a good mechanic and constructor of such things, ignores all but the "functions"

of what he attempts to improve. The conditions of construction and use, also more frequently economic conditions, are overlooked. An inventor is very apt to forget that whatever is performed or attained by a new invention, to be a success it must produce the old result at less cost or a better result at the same cost. This is an inexorable rule, without which "survival" cannot be expected.

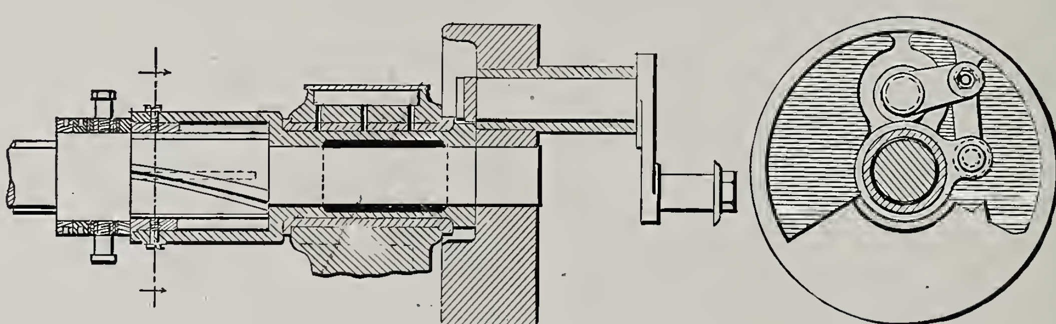
Another thing that will be considered here is the important matter of "added detail." This might properly come under the head of "operative conditions," before mentioned, because it involves maintenance and attendance; but it may be made more plain by quoting a remark once made in England by an experienced designer and constructor of machinery. He said: "The great art of designing machinery consists in leaving out parts and pieces."

These preliminary remarks are not intended for instruction or suggestion, but to indicate the methods that will be pursued in speaking of the merits of new inventions and what is said of them.

U. S. Patent No. 473,906, May 3, 1892.

BULLOCK—STEAM ENGINES.

This patent seems to be a complement to a number of improvements in tube-drilling apparatus, patented at the same time by the inventor. The present patent relates to reversing gearing for steam engines, and is an adaptation of a method much employed on small steamers in Sweden. The Swedish gear, which is simpler, consists of two sleeves on the main shaft, an outer and an inner one, both loose, the inner one sliding through the outer one. The outer sleeve, to which the eccentric is attached, has no movement endwise, but is driven by the inner one, which moves on a spiral key or feather in the shaft, so that both sleeves revolve together in respect to the shaft, the inner one, when drawn out or in, moving the eccentric to the angle of advance each way for running right and left. In the Swedish method the inner sleeve projects beyond the outer one, the extension being formed into a toothed rack by cutting grooves around it, into which a pinion meshes. This pinion is on a vertical shaft, and is operated by the pilot or *styrman*. Even on steamers of some size the engines are reversed by the pilot from the "roof." In the present case there is the same sleeve moving endwise on a spiral key or feather, by



NO. 473,906.

means of a fork and collar; but the sleeve passes through the main bearing, as shown in the drawing, and is connected to a stem extending through the crank pin to an overhung crank or eccentric. The arrangement is ingenious, also is elaborate. It is evidently to meet peculiar conditions of use or application, and will require good fitting.

Of the various methods of reversing the rotary motion of steam engines, those that are most elaborate have succeeded best,—not because of elaboration, but because the eccentrics can be fixed on the crank shaft and a greater stability of working parts secured. The most common method is the link, which for a long time held almost complete sway, down to ten years ago, when there came up various ingenious modifications of radial gearing, such as Joy's and Marshal's, which at first gave prom-

ise of improved functions ; but the link movement is hard to displace.

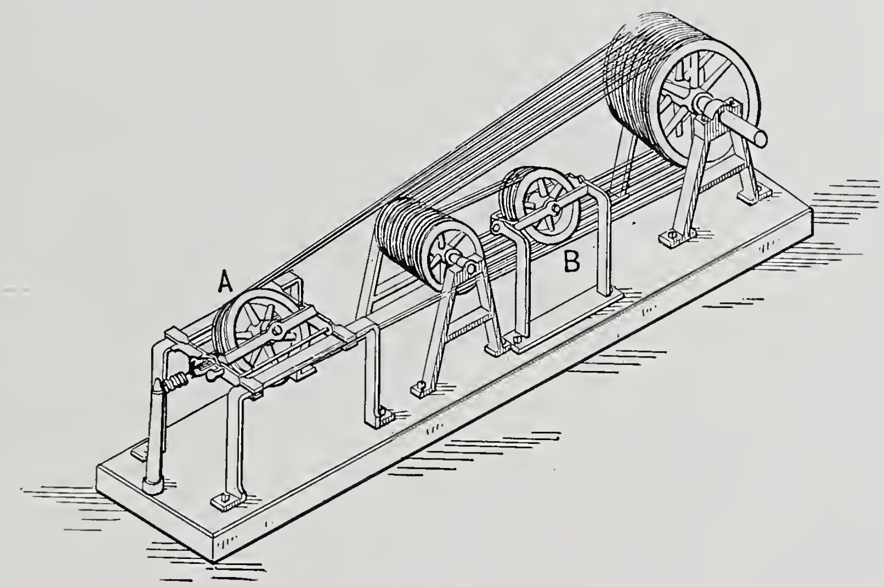
Besides the Swedish reversing gearing before described, there comes to mind another case where a special method has for some reason proved the "fittest,"—the loose eccentric employed by Penn, of London, and others for small paddle steamers with oscillating engines of the overhead-hitch type. The handling of these engines, which can be seen on the Thames "penny boats" around London, seems to be a marvel of convenience. No miss ever occurs, indeed cannot without serious accident. The eccentrics are balanced loose on the shaft, and are so free that a light pressure on the cam-rod will throw the eccentric either way to the angle of advance. There is one example on Puget Sound, where a large portage steamer is operated in this manner with loose eccentrics, and such gearing was once tried at San Francisco, but proved a failure because of "sticking" and permitting the boat to ram the wharves.

The advantages in the present case of this peculiar method of reversing lie, no doubt, in its adaptation to engines to operate diamond-drilling apparatus, of which Mr. Bullock's company is an extensive maker, and in the very condensed form of the mechanism and the fewness of the parts involved. These considerations and others of the kind frequently form a special measure of the merits of new inventions that render general criticism inapplicable.

U. S. Patent No. 488,875, July 12, 1892.

MACDONALD, WILLIAMS AND HITZEROTH—ROPE DRIVING.

The use of wound ropes for driving the first movers in mills and factories has become well known, and after five or six years of successful application has achieved a permanent place among transmitting gearing. It consists, as shown in the drawing below, in winding a common rope around the driving and driven drums, and is arranged in two ways, known as double and single wind. In the single wind the rope passes successively around the two drums, each groove being occupied ; then the rope is trained back to the point of beginning and passed around an idle tension pulley set diagonal to the main drums. In the double wind the rope is first placed in alternate grooves across the face of the drums, and then, after passing around an idle pulley, comes back to the beginning, and is wound again over the same course in the manner shown in the drawing.



NO. 478,875.

In this double-wound system it was found that the ropes had to be "crossed" at some point, usually between the two idle pulleys *A* and *B*, and for a long time this was understood to be an unavoidable feature of the double-rope wind. Mr. Dodge, the original inventor

and introducer of this kind of gearing, when informed that the ropes could be wound without crossing, said it was impossible, and the problem is introduced here partially with a view of furnishing the skilled readers of this magazine with a puzzle problem involving some geometry not laid down in the books.

The inventors say in the patent named: "Our invention consists in the construction of the main driving drums, or the driving and driven ones, with an odd instead of an even number of grooves, so that the strands of the rope when double wound will also be uneven in number, and not crossed between any two drums or in any part of the system."

This declaration at the beginning of the specification embraces the whole gist of the invention. When the grooves or wraps are of an even number—6, 8, 10, and so on—the ropes must be crossed in some part of the system; but when the wraps are uneven—7, 9, 11, 13, and so on—there is no cross of the strands. It seems a queer problem, and was so regarded at the patent office, where a model like the present drawing was supplied for experiment. This, we imagine, was of not much practical value, because if the rope is once removed no one but an expert can put it on again. It seems a simple matter, but is not, as we can bear testimony to from futile attempts of the kind with the same model. The inventors and their attorney could not well furnish a geometrical analysis of the problem; and as their claim of the crossed ropes in the Dodge system had to rest on facts and examples not existent in the patent office, the case became one of some celebrity there; and it was only after a visit to Washington of Mr. Hoadley, a noted expert in this rope-driving gearing, who went to explain the method, that the examiner would risk an allowance of the inventors' claims. Constructor A. W. Stahl, U. S. N., author of a well-known treatise on wire-rope gearing, whose attention was called to this problem, has promised an analysis of the matter, which, if received, will be introduced in these articles in a future place, unless anticipated by some one else furnishing a solution in the interval.

It should have been remarked, in respect to the model before mentioned, that the rope could be wound with either even or uneven wraps, resulting in the crossed or open strands accordingly; and had it not been for the difficulty of winding the rope or cord in either manner, the patent officers would, no doubt, have seen their way to definite action at the beginning. It is one of those curious things that crop out, as in this case, by accident, and of which the analysis is difficult, even after the fact is fully demonstrated.

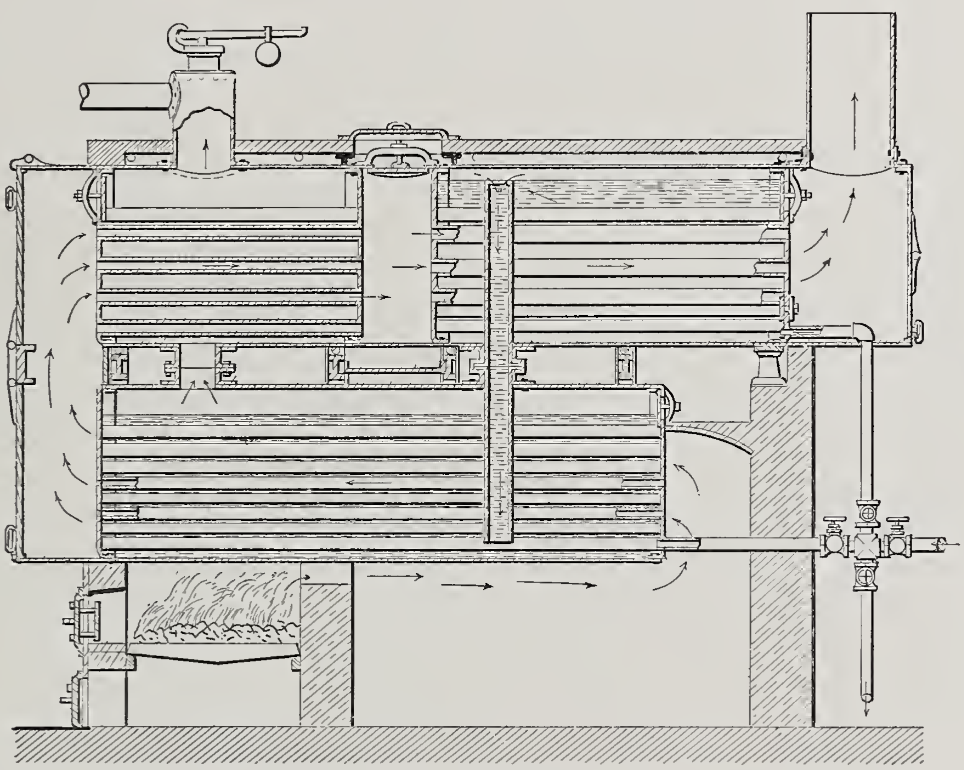
Transmission from first movers is an old and long-debated problem. The best gearing is unquestionably tooth wheels; but such an assumption must include a kind of wheels that are commercially, if not mechanically, impossible. In England, where the making of such gearing has been more perfected than anywhere else, there has been attained all that can be expected. The change wheels, or indeed all wheels on high-class machine tools, are cast, and bevel gearing is made so perfect that it is a common thing for works on the Continent to send to England for wheels that will run without noise. But even with this skill there is a good deal of main driving done with ropes,—not on the "wound" method just described, but on the multiple system. In this country belts—or "bands," which is a better name—are most common; but some examples of tooth gearing have been made that have never been excelled.

One of these was in the Continental hotel, in Philadelphia, made by Messrs. Bement and Dougherty, of that city, for operating the hotel elevator. The cage was driven by a screw 9 inches in diameter, connected at the bottom by a pair of bevel wheels about 20 and 60 inches in diameter, having a 6-inch face. These wheels being in the well-way of the elevator, communicating with all the halls, the least sound could be heard all over the building, so the gearing had to be noiseless. The wheels were made on a kind of banter. Mr. Bement was one of the shareholders and director in the hotel company, and when he proposed in the board to employ bevel wheels for the elevator, other directors, some of

them noted mechanics, objected to tooth wheels on account of the noise. "My wheels do not make noise," said Mr. Bement, and in this case they did not.

After being "machined," as our English friends would say, the wheels were "ground together." The pinion was in two parts, or rather there were two pinions so fitted together as to be slipped and expanded. The wheels were set up in the works and started, the teeth fitting close and of an odd number, so they changed relatively one tooth at each revolution. Emery and oil were put on the teeth, and the grinding went on for days. Whenever the teeth became loose the pinion was expanded or slipped to produce a hard mesh, and the grinding proceeded. Mr. Bement's instructions were that whenever each tooth would cut a hole through tissue paper placed between the wheels the grinding could be stopped. This was attained, and we suspect that this was the only pair of wheels of the size ever made that ran entirely noiselessly, produced by means that are not likely to be repeated.

The other case alluded to was the first movers from the great Corliss engine that drove the shafting in the Centennial exposition, at Philadelphia in 1876, and now in use at the Pullman works, near Chicago. As remembered, these wheels were 5 feet and 30 feet in diameter, 24 inches face, engine cut, and ran without any noise but a dull rumble, perceptible only when standing very near to them. Such gearing is very expensive, liable to accident unless carefully guarded, and perhaps no better than the plain manilla rope employed in the manner shown in the drawing, which costs not more than one-fourth as much as tooth gearing.



NO. 474,385.

U. S. Patent No. 474,385, May 10, 1892.

J. H. HOADLEY—STEAM GENERATOR.

This invention belongs to a class of boilers called progressive heating, wherein the falling temperature of the gases of combustion is adjusted to the rising temperature of the water and steam, and, as shown in the longitudinal section above, differs in many respects from present methods. The drawing being to scale, comprising nearly all the various parts, and the course of the water indicated by arrows, the whole will be understood

with some study, but not perhaps at a first glance.

There has been, considering the objects to be gained and the evident economy of the system in slow boilers, but little progress in this progressive method of heating or generating steam, and in no other case have we seen the same accessibility in boilers of the class. Except in the chamber *D*, there is free access to all tube plates, and even here there is no difficulty if the chamber between is made wide enough to use a hammer.

A typical progressive-heating boiler would be one composed of a series of connected compartments, the temperature of the hot gases decreasing in one direction and the temperature of the water increasing in the opposite direction, so a diagram of the two would make a parallelogram. The feed water would be fed in at the last compartment next the chimney, and steam would be drawn from the hottest one over the fire. There is also the principle of diffusing and breaking up the hot gases between the sections or compartments by chambers, as shown at *D* in the present boiler, and sometimes by baffling plates or walls in addition.

The idea or scheme is good. Its first application, so far as known, was in Scotland and for marine purposes, but the references are not at hand. In this country Mr. John L. Heald, of Heald's Agricultural Works, at Crockett, on Carquinez Straits, near San Francisco, has made some extensive experiments in progressive-heating boilers, the result of which we do not know. The Scotch boilers were superimposed, as in the present case. The Heald boilers were set tandem (so to call it),—a series of compartments in one parallel shell, the feed water passing from the top of one compartment to the bottom of the next one up to the last, where there was steam space provided.

One feature of such boilers is that, the greater part being filled with water and the sections being independent except as to the connecting pipes, destructive explosions are hardly possible. There is also the advantage of increasing the number and area of the tube-heating surfaces, because all sections except the last or steam one can be filled with tubes. The present boiler of Mr. Hoadley's is not presented as a type of progressive-heating boilers, but as one wherein this method is present with other new features of interest to steam engineers.

In considering the efficiency of steam boilers, one of the principal factors is commonly left out: the imperfect combustion of fuel, and there is a good deal of promise at this day for efforts in that direction. It will not be extravagant to claim that boilers themselves have undergone nearly all the experiments that are likely to improve their performance. The compromise between the material required for strength and the barrier thus set up between the water and the hot gases is an insuperable impediment to convection that can be met only by smaller diameters and thinner plates. This and indeed all other features and functions of boilers have been thoroughly studied by the learned and unlearned, without a corresponding success in economic results that can at all be compared with what has been done in dealing with the steam after it leaves the boiler.

In improved methods of burning fuel we are met at the outset with an impediment of a discouraging nature. The fuel must rest on a support beneath it, and the gases of combustion must pass upwards away from, instead of through, the fuel. Fresh fuel must be fed to the wrong side, and its imperfectly mingled gases start off on a journey of imperfect work. It is true we have down draught, water grates, and some degree of success in these, also in bottom feeding, burning on plates and more. Here, we imagine, lies the line of the next successful effort at heat-saving.

U. S. Patent No. 474,286, May 3, 1892.

R. BREWSTER—BEARINGS FOR MACHINERY.

This invention, which can be best explained in the terms of the inventor, may be one of much importance if it have in any great degree, or even moderate degree, the advantages claimed. Its nature is best explained in the following quotation from the patent specification:

"The material I employ is composed

of the following ingredients, preferably in about the proportions stated: Feldspar, 50 parts; rock-crystal, 50 parts; china clay, 30 parts; and flux (preferably borax), 30 parts. These materials are well ground, and combined with water in the usual manner of working pottery bodies or materials; and they are made by the ordinary processes into a comparatively dry clay or body, or into what is known in the pottery trade as 'slip.' The material thus prepared is, when in the state of comparatively dry clay or body, molded into the required shape by the means of dies and pressure, or it may be first thrown and then turned into form, or when in the form of slip it is molded into the shape required by pouring the same into molds, as is well understood in the pottery trade. Steps and bearings formed of the above material are dried and fired, after which the bearing surfaces, if not sufficiently true, will be turned, bored, or ground to the required form, and then polished if required, or as may be necessary. Steps or bearings of the character herein described will be held in metallic or other suitable supports or carriers."

Boring, cutting, and polishing substance, of granular and, as we believe, siliceous nature, is unusual at least, and there is also the question of crushing strain. Various kinds of material for bearings are being invented in rapid succession. One recently exhibited and the subject of a paper read before the British Association at its last meeting, and experimented upon with favorable results by Professor Unwin, gives some promise of success. The material is called carboid, and is composed of pulverized carbon and steatite.

It is extremely probable that some substance may be invented to replace metals for the greater portion of machine bearings, but not so probable that such bearings can be made to operate successfully without lubrication where there is considerable pressure. It is, however, a more promising field for invention just now than a good many others that can be named.

The graphite bearings made at Philadelphia, and the subject of an honorable award by the Franklin Institute, are perhaps the nearest approach ever made to practical machine bearings not requiring lubrication. The use of the material has not at this time been wide enough to determine the chances of survival, and in this remark use must also mean misuse, because that is often a greater impediment than the properties of the thing dealt with.

Aside from dry bearings, which have not yet achieved a place of much importance, the principal impediment seems to be that nothing but metal will resist the solvent action of oils, and to undertake the introduction of any new lubricant would be the labor of a lifetime.

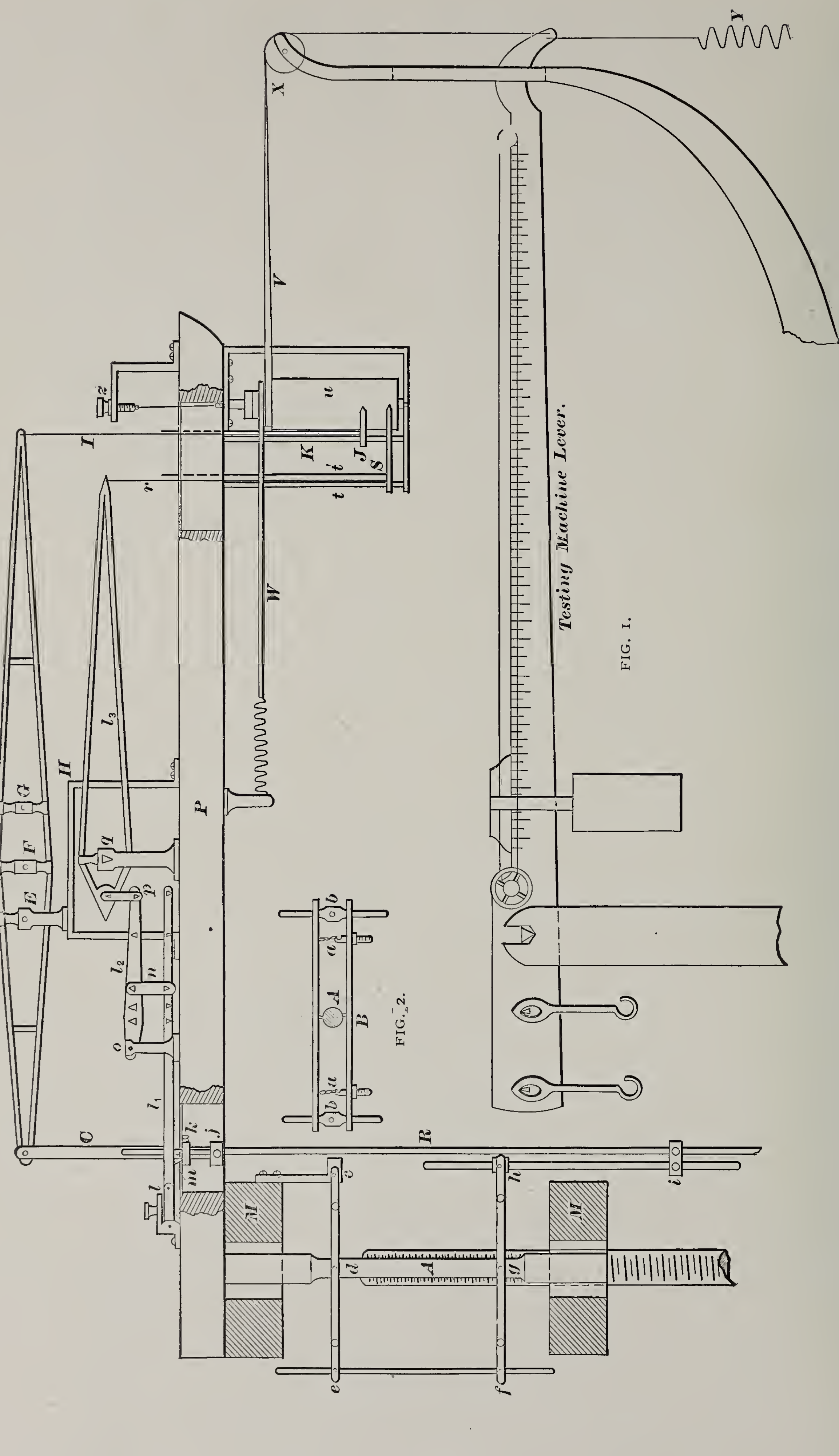


FIG. 1.

FIG. 2.

AUTOMATIC RECORDING APPARATUS FOR TESTING MATERIALS.

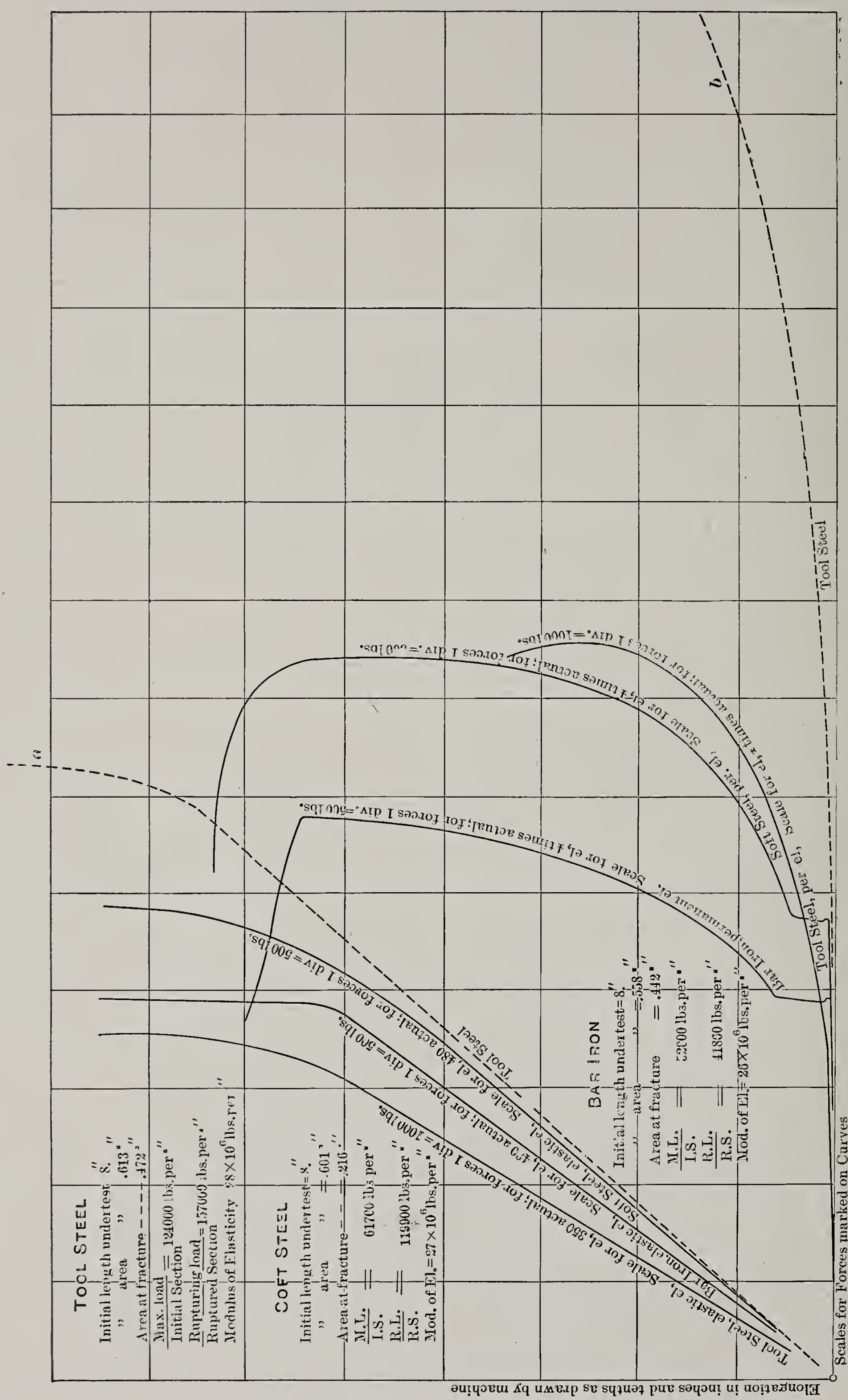
NEW APPARATUS FOR TESTING MATERIALS.*

By Thomas Gray, M.E.

IT has seemed to be important that a reliable and convenient method should be obtained of automatically recording the behavior of different kinds of materials while they are being tested. Considerable attention has therefore been devoted to this subject for several years, and it is proposed in this paper to give a brief description of the latest form of apparatus for recording tests on tensile and compressive strength. This, like several other forms of apparatus which have been contrived for the purpose, draws a double diagram of the change of length of the specimen in comparison with the stress applied during the test. One of these diagrams magnifies the change of length in a ratio varying from 100 to 500 times, according to the adjustment of the apparatus, and is intended only to show the behavior of the specimen for strains below its elastic limit. This range of adjustment for the sensibility enables the full size of the diagram sheet to be taken advantage of for materials varying considerably in their capacity for elastic strain,—such, for example, as timber and soft iron. The other diagram is intended to show the relation of the permanent changes of length to the forces producing them. The scale of this diagram can also be varied to suit the circumstances of the case.

The apparatus is illustrated in the accompanying diagram (Fig. 1), in which *M M* are the two grip crossheads of one of Riehlé's testing machines of the Harvard type. The lower of these crossheads is adjustable in height by means of two screwed rods (one on each side of the grip), which connect the crosshead to the piston of the hydraulic apparatus used for applying the stress to the specimen. To the upper crosshead a beam, *P*, is bolted, and on the top of this beam the recording apparatus is mounted and enclosed in a case. The outer end of the beam *P* is braced by means of stay-rods from the lower part of the platform, carried by the steelyard levers of the machine, so that any distortion of the crosshead does not affect the record. To the specimen *A* two frames of the form shown in the figure are pivoted at *d* and *g* of the main diagram, and at *B* in the detail (Fig. 2). The bars *b b* are round, with the exception of the central block, and are made long enough to allow the side bars to be separated far enough to enclose the largest specimen which the machine is intended to test. The pivots are held firmly in two center-punch holes by means of two flat springs, to which the ends of the chain *a a* are attached. This makes a form of frame which is very easily put in position on the specimen, and which is at the same time rigid in the direction of the forces applied to it. The pivots being placed across a diameter of the specimen, and the recording apparatus worked from the center of the end bars of the frames, insures that bending of the specimen will produce little effect on the diagram. The upper of these two frames is pivoted at *c* to a link hinged to the upper crosshead *M*, then to the specimen at *d*, and finally to a rigid rod, acting as a strut between the two frames, at *e*. The lower frame is hinged at *f* to the strut connecting the two frames, is pivoted to the specimen at *g*, and carries on its free end a link, *h i*, which connects it to the vertical rod *R*. The length of the link *h i* is the same as the length from *e* to *f* of the strut connecting the ends of the two frames, so that if *g* moves relatively to *a* the rod *R* will move just twice as much without any error due to the arcs round which the points *f* and *h* turn. The block at *i* is rigidly fixed to the rod *R*, but is pivoted to a second block, which slides on the link so as to

* Paper read before the American Society of Mechanical Engineers.


TOOL STEEL
Initial length undertest 8."
" area " .613"
Area at fracture .472"
Max. load / Initial Section = 124000 lbs. per □"
Rupturing load / Ruptured Section = 157000 lbs. per □"
Modulus of Elasticity 28×10^6 lbs. per □"
SOFT STEEL
Initial length undertest = 8."
" area " = .661"
Area at fracture = .216"
M.L. / I.S. = 61700 lbs per □"
R.L. / R.S. = 119900 lbs. per □"
Mod. of El. = 27×10^6 lbs. per □"
BAR IRON
Initial length undertest = 8."
" area " = .558"
Area at fracture = .442"
M.L. / I.S. = 53000 lbs. per □"
R.L. / R.S. = 41800 lbs. per □"
Mod. of El. = 26×10^6 lbs. per □"
Tool Steel, elastic el., Scale for el. 350 actual; for forces 1 div. = 1000 lbs.
Bar Iron elastic el., Scale for el. 470 actual; for forces 1 div. = 500 lbs.
Soft Steel, elastic el., Scale for el. 480 actual; for forces 1 div. = 500 lbs.
Tool Steel
Bar Iron permanent el., Scale for el. 4 times actual; for forces 1 div. = 500 lbs.
Soft Steel, per. el., Scale for el. 4 times actual; for forces 1 div. = 500 lbs.
Tool Steel, per el., Scale for el. 4 times actual; for forces 1 div. = 1000 lbs.
Tool Steel
a
b
Scales for Forces marked on Curves
Elongation in inches and tenths as drawn by machine

give the necessary freedom of motion. The rod R slides in guide blocks fixed to the machine near the upper and lower ends of the rod. It is evident that by clamping the frames at the proper distance apart on the rod $e\ f$, any length of specimen may be used. It will be readily seen, also, that since the point c is practically fixed relatively to the machine, the point h will also be fixed so long as the specimen does not change length, and therefore slipping in the grips does not affect the record. If, however, the specimen stretches, the rod R will move down through distance equal to twice the change of length between the points d and g. The record of the elastic elongation of the specimen is made by means of the system of levers, l_1, l_2, l_3. The left-hand end of the lever l_1 is pivoted to a hinged piece, l, which can be raised or lowered by means of a screw so as to adjust the position of the record pen. Passing from the hinged piece l, the lever l_1 rests through a knife edge and a vertical strut, m, on a block, k, clamped to the rod R, and its forward end is carried by the lever l_2, to which it is connected by the link n. The lever l_2 rests by a knife edge on the supporting pillar at o, and its forward end is carried by the lever l_3, which it helps to counterpoise. The lever l_3 rests by a knife-edge bearing on a pillar at q, and carries on its forward end a pen, s, which is connected to the lever by a light thread. The pen s consists of a very small ink-well, furnished with a capillary opening opposite the paper on which it writes. This pen is carried on the end of an arm, s, and is guided to move vertically by means of the fixed rod t and a light rod t_1 fixed to s and guided at its upper end. The length of the supporting thread r is made about in the same ratio to that of the link p as the ratio of the long to the short arm of the lever l_3, allowance being made for the motion of l_2. The ratio of the arms of the lever l_3 is 10 to 1, but by changing the position of the link n the combined ratio of the other two levers may be made either 5, 10, 15, 20 or 25 to 1, thus enabling the magnification of the record to pass from 100 times to 500 times by convenient steps. This amount of magnification is found amply sufficient for any ordinary material if the specimen be a few inches in length, the observations on a specimen 8 inches long being equivalent to direct observation on a bar 330 feet long. It will be noticed that the method of attachment here described allows the block k on the rod R to move away from the strut m, and thus to leave the sensitive system of levers unaffected by elongations beyond the range of the diagram. Immediately permanent set and flow of the material sets in, the pen s moves suddenly up against a stop on the rod t, and the levers are unaffected by the subsequent stretching. The very beginning of the permanent set is thus obtained with great accuracy.

The permanent elongation of the specimen is recorded by means of the lever D, which is connected to the rod R by means of the connecting rod C, and rests on a round axis at E or F or G, according to the scale of the diagram desired. The first of these positions for the axis magnifies the elongation four times, the second three times, and the third two times. This lever produces its record by means of a pen, j, which is precisely similar to s. With regard to the dimensions of the parts, I may state that in the apparatus now being used at the Rose Polytechnic Institute the lever D is four feet long. The shortest lever arm in the whole apparatus is thus about two inches, a length which can be measured with considerable accuracy even if no direct method of standardizing the system could be adopted. The long levers are made of light, hard steel rods, and have the form shown in the diagram, which insures a very light and yet rigid system.

The record is made on a sheet of paper wound on the drum u. This drum is pivoted on straight bearings at top and bottom, and its weight is carried by a thin steel wire attached to the adjusting screw z. The drum thus turns very freely, and care is taken to arrange the driving apparatus to insure little or no pressure on the bearings. The drum is provided with two sets of double pulleys of different sizes placed near the upper end of the axis. Supposing, as shown in the diagram, the larger set to be in use, a silk tape is placed on each pulley, and the end of

one of these tapes carried over the pulley x and attached to the end of the testing-machine lever through a special slip-grip arrangement not shown in the diagram. The other tape, w, is attached to the end of a light spring capable of elongating by an amount equal to the circumference of the pulley. These two tapes pulling against each other in the same plane produce no pressure on the axis. The position of the end of the machine lever is controlled by a spring of the proper strength, the elongation of which by the pull on the specimen under test causes the drum to revolve in proportion to the stress applied. The horizontal scale of the diagram is thus proportioned to the strength of the spring y, and this scale is usually obtained by comparing the vertical motion of the pen for a pull on the specimen measured by the sliding steel-yard weight with the motion of the pen for any convenient displacement of the drum round its axis when controlled by the spring. For standardizing tests of this sort a hard steel bar is placed in the machine, so as to avoid trouble due to "set" during the test. The stresses indicated by the instrument are thus the same as those which would be obtained by testing with the sliding weight. It will be observed that provision is made in this form of the apparatus for producing a diagram to rectangular coördinates. This is the chief difference between the apparatus here described and that which I have used for several years in which the pens were attached directly to the ends of the levers.

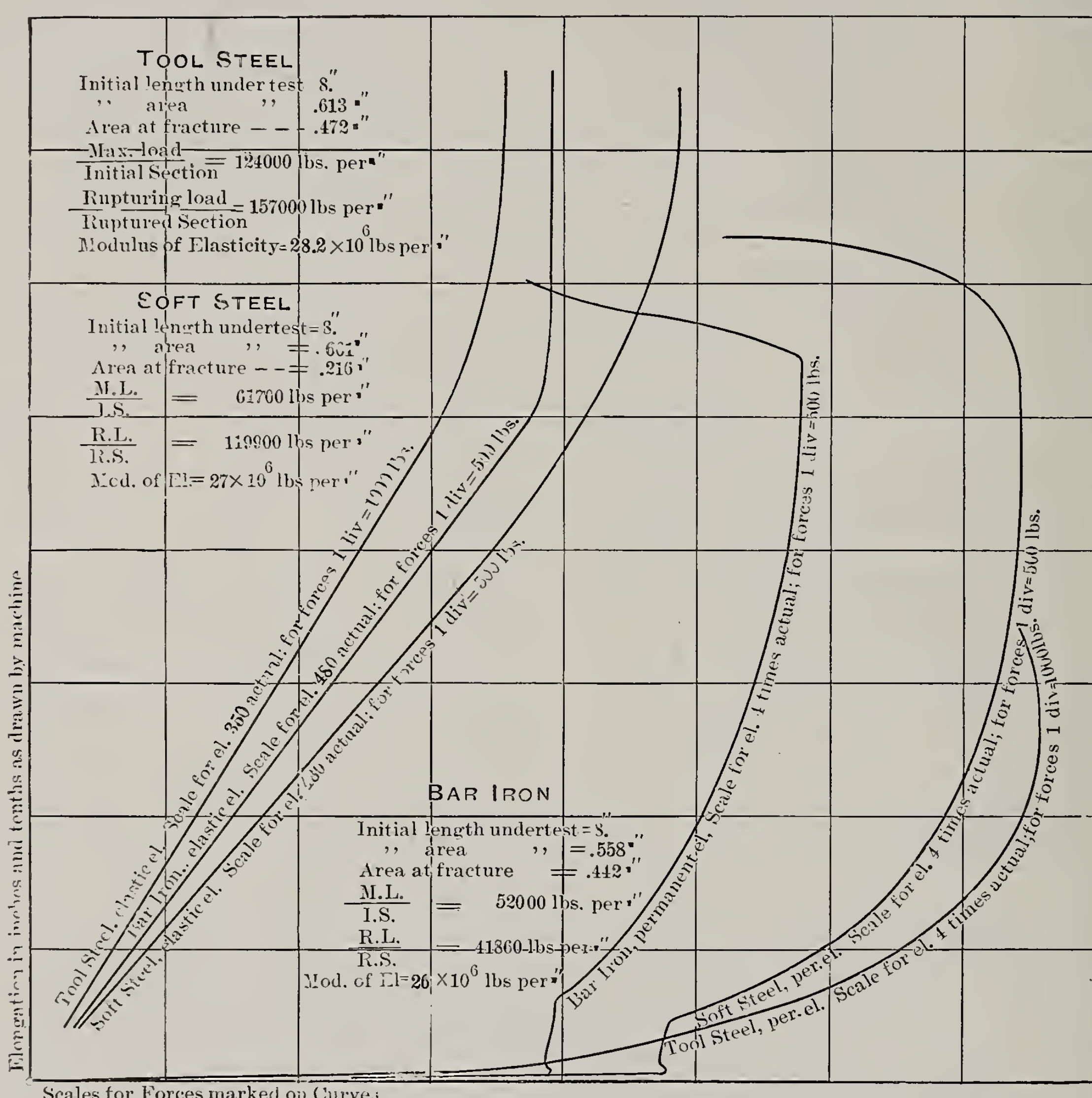


FIG. 3.

When materials are tested for crushing strength or for elasticity under compressing forces, the specimen is placed below the lower crosshead m, which is

then pulled down on it, producing compression between the crosshead and the sole plate of the balanced part of the machine. A longer link has then to be used to make the connection to the point *c*, or, as is found rather more convenient, the bar *e c* is placed below, and a strut connection made to the sole plate instead of the link to the upper crosshead. The method of obtaining the diagram is otherwise identical with that already described.

For cross-bending tests the same indicating apparatus is used, with some simple modifications of the attachments; but as this part of the testing apparatus will probably be modified in the near future in accordance with some new plans which have been thought out, detailed description is left to another opportunity, when the whole subject of cross-bending tests can be discussed.

The annexed diagram (Fig. 3) illustrates the record obtained by this apparatus. The curves marked (1) were obtained from a round specimen of tool steel .884 inch in diameter. The specimen was made from bar steel 1⅛ inches in diameter, and was turned down over a length of 9½ inches, the shoulder curving gradually from the larger to the smaller diameter. It will be noticed that in this specimen there is no definite yield point such as is shown in a marked manner in the other curves. The specimen draws down nearly uniformly, and shows very little local contraction. The curves marked (2) were obtained from a specimen of soft steel .875 inch in diameter and similar in form to the tool-steel specimen. In this case there is a marked elongation with nearly constant strength a little past the elastic limit, and there is a considerable falling off of strength before rupture and during the period in which local contraction takes place. The strength at the point of rupture is, however, very much higher than that obtained by taking the ratio of the maximum load to the initial area of cross-section. The curves marked (3) were obtained from a specimen of ordinary bar iron. The part under test was initially .884 inch in diameter, the shape being the same as that of the other two specimens. This specimen behaves similarly to the soft steel at the yield point, but has a much less gradual falling off of strength just before rupture, a peculiarity common to several diagrams taken from this iron. The strength at rupture, reckoned on the ruptured area, is in this case less than that obtained by taking the ratio of the maximum load to the initial section. The local contraction of section before rupture was, as will be seen from the figures in the diagram, much smaller than that given by the soft steel, although the fall of strength was about equally great. The character of the fracture was similar to that usually obtained for material of the kind experimented on.

In determining the exact magnification given by the sensitive system of levers, the most convenient arrangement is to introduce a micrometer screw in the rod *e f*, by means of which the length of the rod can be changed by a known amount, and the corresponding rise or fall of the pen observed. Some care has of course to be taken to insure accuracy in the use of a standardizing device of this kind, but the necessary precautions will readily suggest themselves to any one having experience in such measurements.

THE FRICTION OF LUBRICATION.

By Prof. R. H. Thurston, Director; Sibley College, Cornell University.

IT is now a century since the famous experiments of Coulomb, in which, for the first time probably, scientific observations were made upon what was then thought a matter of such slight importance.* It is over half a century since Rennie determined the laws of the friction of solids.† It is just half a century since General Morin summarized his work in the same field on the erroneous assumption that the laws of solid friction and those of the friction of lubricated surfaces are identical.‡ His mistake, like that of Carnot in a different field, did not vitiate his own conclusions nor detract from the value of his experiments in themselves; but the inference that they were capable of supplying a basis for the enunciation of the laws of friction of lubricated surfaces, and for deductions of defects of efficiency in any machine and under whatever conditions of pressure and speed of rubbing, has probably been productive of many important mistakes by engineers.

This later and still valuable work of the great French investigator has stood almost unchallenged by writers of subsequent times, until within a very few years, when the researches of Thurston and Woodbury in this country, of Tower in England, and sporadic work performed in all countries and in all departments of engineering, led to a more exact knowledge of the subject, and the rejection of the work of Morin and his predecessors as representative of universal practice. It is now well known that although those figures are correct for such conditions as they fairly parallel they are often widely astray under other conditions, and that not only may the coefficients of friction be sometimes much larger than those tabulated and taken as standard by Morin and his followers, but coefficients may be obtained, at times, not a tenth their magnitude.

The first experiments revealing the fact that the laws of lubricated friction and their coefficients differ from those of solid friction seem to have been those of the late G. A. Hirn.‖ This eminent engineer, according to his own comparatively recent statement, completed his work in this investigation about the end of the year 1847. He had made his experiments very extensive, and under a great variety of conditions and on various parts of machines. He was only able to publish the results, however, in 1855.§ Precisely why he was so greatly impeded is not stated, but the impression produced upon his readers is that they were so little in accordance with the published and universally accepted work of the then more distinguished authority that the young aspirant for truth was condemned unheard, and effectually repressed by the societies in whose transactions he desired to incorporate his records. His powerful and distinguished patron, Professor Combes, finally secured their acceptance and publication in the *Bulletin de la Societe d' Encouragement*. The following is the code which he enunciates as the result of this research:¶

"1. There is a great difference between the phenomena which are presented in the friction of two pieces sliding the one upon the other, accordingly as they are dry and immediately in contact, or as they are separated by a film of lubricating substance (oil, grease, air).

* See Chap. VI., Thurston's "Friction and Lost Work." New York: J. Wiley & Sons.

† "Philosophical Transactions," 1829, p. 169.

‡ "Experiences sur la Tirage des Voitures," 1842.

‖ "Notice sur les Lois du Frottemant." Par G. A. Hirn. Paris: Gauthier-Villars.

§ *Bulletin de la Societe Industrielle de Mulhouse*, 1855.

¶ *Comptes Rendus Hebdomadaires de l'Academie des Sciences.* T. XCIX. Institut de France.

"2. In cases of friction such as I call 'immediate' the coefficient of friction, or the ratio of the weight which presses the two parts together to the driving effort, is independent of the velocities of relative motion of the rubbing surfaces.

"3. This is not the case with what I call 'mediate' friction, or such cases as those in which the two surfaces are separated by an unctuous substance. Here the coefficient of friction is always a function of velocity, of pressure, and of extent of surfaces in contact.

"4. In consequence of the intervention of many causes of embarrassment, of which it is easy to see the origin, but which it is often impracticable to prevent, it is very difficult to determine with precision the laws which govern these phenomena. The quantity of the lubricant, the temperature, etc., frequently cause a variation of the coefficient of friction during the same experiment.

"5. Meantime, however, it may be asserted that, in the ordinary condition of the rubbing parts of our machinery, the journals, guides, etc., the force required to overcome this resistance is proportional to the square root of the surfaces of contact to the square root of the load upon them, and, when the lubrication is abundant, to the velocity of rubbing.

"6. The influence of velocity is always complex. At high velocities, at least when the pressures are light in proportion to the extent of surface, a large number of liquids, widely differing in character from the oils, may become lubricants. Even the air, under certain conditions, and when it is drawn between the surfaces in sufficient quantity, becomes the best of lubricants, the coefficient falling to as little as 0.0001. When, on the other hand, the velocities are low, or when the load is considerable in proportion to area of rubbing surface, the unctuous material may be expelled; the 'mediate' friction becomes 'immediate,' and the coefficient may rise to from 0.01 to 0.2."

This work of Hirn became known but slowly, and in English-speaking countries remained unknown for many years. In "Friction and Lost Work," the only extended treatise on the subject, it is mentioned; but no details were known to its author at the time of its publication, notwithstanding his acquaintance and friendship with the great engineer, to whom he dedicated the work.

M. Marcel Duprez, as appears from the notice in *Comptes Rendus*, 1884,* performed some experiments which led to precisely similar results; but by that time the experiments of Thurston and his successors had given an enormous fund of information on the subject, and had fully corroborated the general conclusions derivable from Hirn's earlier researches. These investigations were inaugurated by the invention of the now standard lubricant-testing machine, designed to secure "precisely the conditions of actual use," and, begun about 1874, were fruitful at once of much valuable information, which was published from time to time from 1878 to 1880.†

Woodbury's work, previous to 1884,‡ and the later work of Tower on flooded journals and the bath system of lubrication, especially,|| have thrown a flood of light upon the subject.

The whole matter may probably be summarized in the following statements: With free lubrication and light loads, the rubbing surfaces are separated by a film of lubricant, the resistance is measured by its fluid friction, and its variations are those indicated by the laws of fluid friction. Under heavy loads and with restricted lubrication, the solids are forced into more or less perfect contact, and the film is squeezed out, leaving them only slightly moistened by the unguent; the friction then approximates in character what is distinctively known as "solid friction," and its variations are those indicated by the well-known laws of friction of solids. Ordinarily the fact is intermediate between

* *Comptes Rendus*. T. XCIX., Nov. 17, 1884.

† "Friction and Lubrication." R. R. Gazette Publication Company, New York, 1878. "Friction and Lost Work in Machinery and Millwork." New York: J. Wiley & Sons, 1885.

‡ Trans. Am. Soc. Mech. Eng., Vol. IV., 1884.

|| Trans. Inst. Mech. Eng. of G. B., 1883.

these typical cases, and the laws of lubrication in machinery are an indefinite function of the two sets of principles. These facts are now so well known, and so well established by countless experiments and by so many investigators, that the older confusion of ideas relative to the two sorts of friction and their influence in the working of lubricated surfaces, and in machinery generally, may be considered to be thoroughly eliminated among well-read engineers and experienced practitioners. It still remains, however, to determine minor questions, and to analyze more completely the complex phenomena of imperfect lubrication, and, in practice, to devise means of insuring that perfect lubrication required to give maximum economy of power and safe and permanent working conditions.

A certain degree of efficiency of lubrication is insured in practice by the fact that defective lubrication results in the heating of journals, and their temperature is thus a gage of the effectiveness of the system, and a warning to the attendant in case of serious deficiency of the lubricant. This also insures an approximation, at least, to free lubrication, since it is necessary to supply oil enough to keep the surfaces out of contact, and to insure fluid friction to prevent heating. Were it desired to obtain the exhibition of the laws of solid friction, it would be necessary to resort to artificial cooling of the journal and its bearing.

It thus happens that, practically, the lubrication of our machinery is largely what Hirn would call "mediate." It should, wherever possible, be made mainly so. The gage of efficient lubrication is the completeness with which the conditions of fluid friction are produced, whatever the kind of surface or character of machine in question. The introduction, therefore, of "water-cooled boxes," while in itself an element of safety, is less a step in the right direction than the introduction of a flood of the lubricant, with suitable provision for its thorough circulation and economical use by proper purification as it becomes charged with foreign matter. A flood of water rather than a flood of oil is a step in the wrong direction, though unquestionably in many cases the former is a desirable element of insurance against accident. Flooded journals and the bath system are themselves an insurance of cool bearings.

One of the most interesting investigations which have been recently inaugurated in the Sibley College laboratories at Cornell University is that in which it is sought to determine what is the method of change from the laws of fluid to those of solid friction when the quantity of the lubricant is gradually and steadily diminished. The problem as enunciated originally was: Devise a system of oil supply which shall at first flood the journal with the lubricant, which shall slowly, but constantly and uniformly, reduce the supply in such manner that a series of observations may be taken which shall afford the data for a graphical representation of the law of variation of the coefficient of friction, as it changes from that due purely fluid friction, as nearly as may be, to that due the laws of friction of solids. A smooth curve is to be obtained if practicable; if impracticable, the causes of variation are to be sought, and as far as possible removed, and the research concluded under as exact and unvarying conditions, other than those prescribed as variable, as is possible. The lubricant is to be measured by weight and by volumes, and the times and pressures are to be reduced to standard units.

In this investigation, finally reported to the American Society of Mechanical Engineers, one of the "railroad oil-testing machines" devised by the writer and built by the Pratt & Whitney Company, as a standard form of the machine, was fitted up.*

The several parts of the arrangement are as follows:

A speed indicator, thermometer, giving temperature of bearings, rubber tubes for circulation of water through the bearings, burette, furnishing supply

*"Friction and Lost Work in Machinery and Millwork." Thurston. New York: J. Wiley & Sons.—Frontispiece, Trans. A. S. M. E., 1890.—"Manual of Experimental Engineering." E. R. C. Carpenter. New York: J. Wiley & Sons, 1892.

of oil, siphon controlling supply of oil, candle-wicking, copper rod.

The burette served to measure the rate of flow of the oil; the adjustable siphon gave the power of regulating flow; and the machine with its thermometer gave all other needed means of securing the desired data. In operation, the natural and steady reduction of rate of flow with falling head in the burette permitted the observer to follow the relation of rate of flow and inverse change of friction resistance until the latter became a maximum at a flow approaching zero so nearly as to cause the metals in contact to become abraded. The object of the experiment was to ascertain where this critical point would, in this particular experiment and in other cases of sensibly the same character, be found, and what is a fair margin of safety in feeding oil to such journals.

It was found that, as might be expected, at low rates of feed the effect of pressure in modifying the values of the coefficient of friction disappeared, the action being that known as friction of solids, instead, as is desirable, as nearly as practicable that of friction of fluids. In the former the friction is great, in the latter small; in the former case it actually becomes a less and less tax upon the machine proportionally to the work done, in the latter it not only is a comparatively large tax upon the motor, but this adjustment of flow is sure to bring with it danger of abrasion, of serious injury to the bearing surfaces, and even break-down of the machine. This last result has been frequently illustrated in serious accidents to steam engines coming of inefficient feeding of the lubricant, especially at the crank pin. The curves show the difference, also, where total pressures on areas of about 20 square inches are reduced from 4000 to 200 pounds, or intensities of pressures vary between 100 and 400 pounds per square inch of projected area of journal. The approach of the critical point with reduction of rate of feed is signaled clearly by the irregularities which appear in the values of the friction coefficient, showing plainly the fact that metal is beginning to bear upon metal, and abrasion is becoming more imminent, and is probably actually occurring in spots on journal and bearing.

The important deduction from this comparison is the following: When the friction of journals in their bearing, or of rubbing parts of machinery, one upon another, is such that the variation of the coefficients follows the law of solid friction, the rate of feed is both uneconomical and dangerous. The fact of this method of variation is a proof that the rate of feed of the lubricant should be at once and considerably increased.

It may be taken as an invariable rule that the friction of lubricated surfaces in machinery should always be reduced to such a point by a free supply of the lubricant that the method of variation of that friction with varying pressures should be characteristic of what Hirn called "mediate" or mixed friction, and as nearly as practicable to that characteristic of the friction of fluids. That this is not the fact, frequently, in practice, is no objection to this principle, but simply an illustration of the common observation that ignorance, thoughtlessness, and carelessness are the characteristics of too many men who have charge of important work, and that this, which should, as one would think, be an obvious conclusion, has comparatively seldom attracted attention, even from the most intelligent. The best way of insuring the operation of machinery in this manner is the adoption of either the well-known "oil-bath" system illustrated in the lubrication of railroad journals, or the poll lubrication such as is seen in the Westinghouse engine crank case, or, in many cases, the arrangement of a system of pump supply to an elevated tank from which streams are led to all journals, keeping them flooded to the utmost, the surplus passing down into the lower tank from which the pump takes its supply. This would probably be, in most cases, an economical system, however costly, in its reduction of the loss of power in friction, and, if we may judge from the relative costs reported for New England mills and other large aggregations of machinery, would usually give an enormous return on the investment. It is

this which gives special value to the better classes of self-oiling shaft bearing used on line shafting in mills and elsewhere.*

The actual rate of flow desired is that which carries the fluid into the capillary space between the journal and bearing in as large volume as possible; and anything more than this is simply overflow, and, with the usual crude arrangements of oiling devices, waste. With a good system of poll or oil bath, this takes care of itself; a surplus is always desirable and is always insured; while with the pump system the only objection to an otherwise desirable large surplus feed is the minor fact that it gives a little more work for the pump. A considerable surplus is probably always, on the whole, advisable here. The danger line is approached, as seen in the experiments last quoted, when the rate of feed, even on a very smooth and well-cared-for journal of steel running in bronze boxes perfectly fitted, becomes something above .003 cubic centimeters per square inch of projected area of journal per minute; and this is equivalent to about 0.05 cubic inch on the same area in the same time. For less perfectly fitted journals the limit is much sooner reached, and it is advisable in all cases to adjust flow to a very much higher rate, making effective provision for collection, purification, and return of the overflow. The purification is as important as the return, and can always be cheaply and well performed. Lubrication, when these principles and these precautions are observed, will be found to be inexpensive in first cost of oil, safe as an insurance against hot journals, and an enormously profitable investment.

* For some extraordinary statistics on this point, see the final chapter in "Friction and Lost Work," in which the author has collated and reduced to figures some of these comparisons of costs and economies.

THE INFLUENCE OF LONGITUDE ON ROPE DRIVE.

By Robert Grimshaw, M. E.

THE author of the London *Electrical Review's* notice of my article on rope drive in *Cassier's Magazine* notes things which I did not write, misapplies things that I did write, and does not note what I did say. As to the statement that a single break in the American system destroys the whole drive, there is so little strain on any individual fold of the rope. and that strain is so perfectly measurable, that as a matter of fact breaks do not occur often enough to be taken into account. The disadvantage of the English system of many splices is that it is impossible to put on any two of the strands the same degree of tension, or to know how much tension there is on any one of them ; in consequence, that one of a set of new ropes which is under the greater strain goes first, and the others follow in the order of their tensions and in the inverse order of their strengths, thus necessitating a constant series of stops, and leaving the system, after the first break, with a number of pieces of different strengths and different unknown degrees of tension.

I should be obliged to the writer of the paper if he would name some establishments in England in which "all cast gears are running, for practical purposes, noiselessly." I have been in high-grade English mills, and heard cast gears growling at a great rate ; and there are many other English (and with English I include Scotch and Irish) mills which it is not necessary to enter or even to approach in order to know that cast gears are running there.

That leather belts occupy a middle position between cast gears and ropes in the matter of friction to transmit a given power I am willing to admit ; but as I did not state to the contrary in my article, it has no bearing on what I did say. But that it absorbs five if not ten per cent. more power to transmit a given power through ropes than through gears, I am not prepared to admit, knowing many instances to the contrary in those lines where both ropes and gears have been used, to say nothing of the thousands of cases where ropes are in daily use and in which the friction by gears would be so great that they have been out of the question.

That gears "as ordinarily made" are not so mated that all of a pitch will mesh together, I said and stick to. It is only where they are extraordinarily made (as is the custom in only about one out of five shops) that they will do what they should do, and what the *Electrical Review* claims that they actually do ; and the exception allowed by the *Electrical Review* in the case of bevel wheels represents just the most important class of gears for carrying large amounts of power.

That English gearing is superior to that of America I deny,—not because I am an American, but because I have never seen any gearing made in Great Britain which will match that which we have shown at our exhibitions ; and I know that the American system of gear-cutting with standard milling cutters, such as those made by Pratt & Whitney and Brown & Sharpe, give better results, where such cutters are used, than are produced abroad, and the proportion of shops where such cutters are used, while smaller than it should be, is, I believe, greater here than in Great Britain. I as freely acknowledge what I have not been asked by my critic to admit : the superiority of average English rubber belting over average American, as I claim superiority of average American gearing over average British.

As to the varieties of ropes that I did not mention, their number is legion, and I could not have noticed them in a

short magazine article. Some of them, had I been writing a volume on the subject, I should not have noticed save perhaps to mention that they existed.

That the fiber rope running in a wedge groove has the disadvantage that every rope on a wheel may be running upon a different diameter, and that this causes the excessive friction of rope-drive systems, is something that I do not admit for two reasons: first, there is no such excessive friction to be caused by that or anything, in a properly planned rope-drive system; and second, the average effective diameter runs about as equal with this system as any belt drive. If the ropes or the belts are of even diameters, the effective diameters will be the same; if they vary, there will be a slight difference of speed with both ropes and belts, but in no case will that be enough to make much difference in the friction, because in any wrapping connector there must be a certain amount of elasticity (enough to make two per cent. of "creep"), or that wrapping connector will not drive; and there is no system in which that two per cent. of elasticity would not more than take up the infinitesimal speed-variation caused by this hypothetical variation in effective diameter. I might add to this that I am by no means strictly wedded to the wedge-groove system, and do not defend it as my own, but simply because it is wrongfully attacked.

As to the sliding-frame system not being "neat," that cannot be said by any one who has seen it applied by our American system. What it may be abroad I do not know; but even if it is not "neat," its object is not to secure neatness, but absolute uniformity of tension under variations, conditions of load, weather, etc. What it is intended to do it does to a degree of perfection that makes it possible to graduate the carriage frame of such a system to serve as a barometer; and, even if it were not neat, it would be better to have it than to have fifteen different tensions for a 16-rope drive, as in the English system, and to have some of them belly so low that they touch the bottom fold while others are taut.

As for it not being "good practice" to run ropes vertically between shafts, anything is good practice that does the work effectively just as it is designed to do, and without excessive weight, original cost, or repair bills. And further, any one who has ever been bothered with a 48-inch belt between a horizontal shaft in the basement of a grain elevator, and another horizontal shaft 150 feet above, at the elevator head, will understand how very much better a rope is than to have the belt hanging down 1½ inches from the lower pulley by reason of its own weight, and have to be kept up against it by binders. In such a case a belt is bad practice and a rope is good practice; and in fact it is just in the case of vertical connections between horizontal shafts that rope drive has the greatest advantage over flat belts.

As to centrifugal tensions, they cannot exist along straight lines of motion. If a rope is properly confined at the points where it takes off at a tangent from the pulleys, it may be run 20,000 feet a minute without slinging away in a convex curve.

That the American system of rope drive is better for secondary driving than for main transmissions may be the case. It is certainly the case with flat belts; but that does not do away with the fact that, with either main or secondary lines, rope drive is capable of doing better work than flat belts.

As to the statement that "the American system seems to be based upon a mistaken idea that ropes need to be very tight in order to work," I agree with the writer of the criticism that it is a mistaken idea, but beg to add that his is also a mistaken idea that such mistaken idea is American. The essential feature of the American "single rope and many fold" system is looseness, and to guard against tightness the tension on each fold of the system is not only the same as that on every other fold, but is known and completely within control.

I might say, in conclusion, that my original article was not based on a superficial knowledge of the subject; for twelve years ago, when I stopped counting my tests of belts and other wrapping connectors, I had made over

1200, under as many different conditions as could be produced. During the first 300 or 400 I changed my views several times on the subject of that class of transmission ; after 500 or so I got to be able to predict pretty nearly what to expect, the results being a question merely of degree, and not of manner; and after about 1000 test results seemed to repeat themselves so often that the subject ceased to be interesting. If my critic has any data resulting from actual tests, I should be glad to have them. Many of mine were published years ago.

LEADING AMERICAN ENGINEERS.—JOHN WALKER.

By S. Groves.

THE well-known phrase, "Necessity is the mother of invention," was never better exemplified than in the great improvements which have been made in cable railway machinery.

Every engineer of an observing mind must have noticed, during the early history of cable transportation, the great wear and tear which took place on the cable and winding drums. The life of the good cable is at best but a short one, but the later improvements have, as is well known, lengthened this life materially. About six years ago, or, to be exact, on the 22d day of May, 1887, John Walker, whose manufactures since that time have become known throughout the world, was in the power house of the old Ninth Street Cable Railway in Kansas City, and was intently watching the sparks flying from the large winding drums, as the steel cables dashed around the groove gearing, and cutting their way at every revolution. This deplorable wear and tear presented to the observer's mind a problem. Could this defect in the life of cable machinery be remedied, or if not entirely remedied, reduced? At that time Mr. Walker was temporarily in the city, and after some study and thought he returned to his hotel, the Coates House. Almost before he was aware of the fact he had completed a sketch of a cable-driving device from which has sprung the largest manufacturing business of its kind in the world.

Mr. Walker is to-day forty-six years of age. He was born on August 3, 1847, at Middlesborough, a town situated on the rugged northeast coast of England. His father, James Walker, was an iron founder, who could sleek a mold, fix a core, pour a casting, and, as has been said, could make a contract as well, with the best workmen in the great foundries of the ironopolis of England. It was here, amid the blast furnaces, rolling mills, foundries, shipyards, docks, in sight of the German ocean, grand old Cleveland hills, and purple moors of Yorkshire, that John Walker first saw the light, and where he spent his early years. He was educated first in a common school, finishing off at the private academy of Thomas Ainsworth, a stern old pedagogue of the ancient *régime,* and then served seven and one-half years of apprenticeship in the workshops of Bolchow, Vaughan & Co., Middlesborough, the largest iron concern in the world, with a capital of fifteen and one-half million dollars. Even before he attained the age of seventeen years his mechanical and inventive genius began to manifest itself. There is in existence to-day a primitive model of a steam engine which he constructed in his early apprenticeship days. His aged mother, who is now ending her days serenely under his care, on the south shore of Lake Erie, delights to tell how John would return from work, and after preparing himself in society attire, instead of rushing off to the theatre or the dance, after the manner of many of the engineering students, would spend the evening over a drawing board or sheet of figures in serious study.

Mrs. Walker recently told the writer that she was often startled to see her son, after having retired, arise and begin to figure out some perplexing problem at two or three o'clock in the morning. His first experience was obtained in the workshops of Leeds and Manchester; but Mr. Walker, like many other engineers, was not contented to remain where he was, and in 1871, having had considerable experience both in machine shops and as a pattern-maker, he decided to come to America. His first connection was in a good school,

JCHN WALKER.

for soon after he arrived in Philadelphia he found employment with the well-known firm of William Sellers & Co. It was during his connection with these eminent engineers that he conceived the idea of a gear scale, for use in setting out graphically the form of teeth for gear wheels.

Mr. Walker's scale is still recognized as the most simple and expeditious, as well as scientific, method for laying out the teeth of gear wheels. Every engineer has heard of Professor Willis, of Oxford. There may have been some question as to whether the Walker method was equal to the elaborate odontograph of Professor Willis; but Mr. Walker's plan seems to have supplied the necessities of perfect gear teeth, which should have :

First, the point of contact near the base of the pinion tooth ;

Second, the harmonious rolling of the gears ; and

Third, that all wheels of same pitch must be interchangeable.

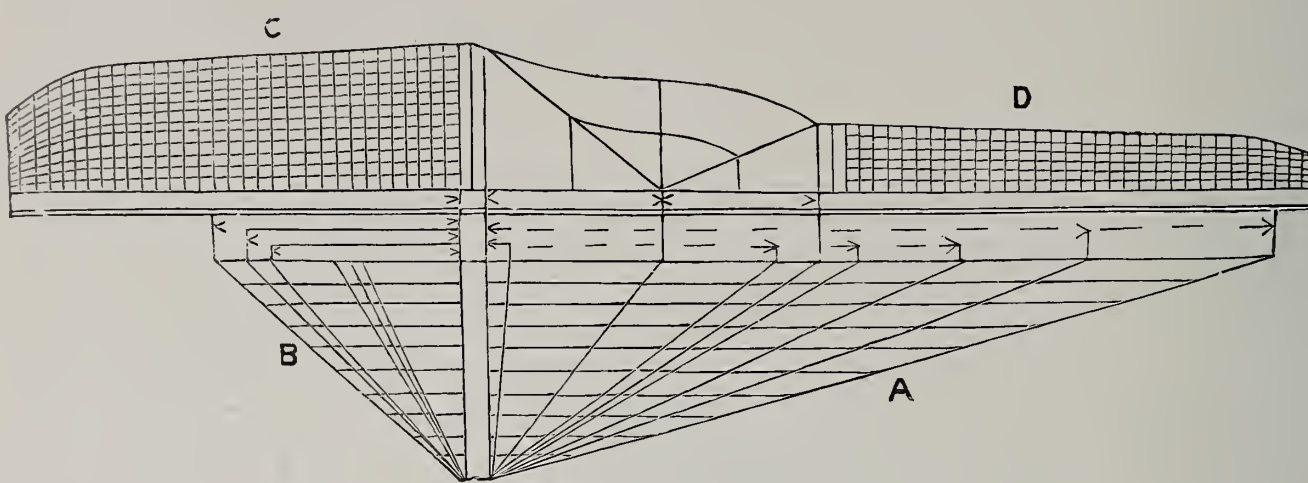
It will be seen from the illustrations on this page, of both the Willis and the Walker plans, that the latter's design supplies all the essentials necessary for a strong, effective gear tooth. Within a year after Mr. Walker's first application of the scale, it was adopted by the Southern Pacific Railway Company for use in their machine shops on their entire system. During the past 20 years over 500 of these scales have been sold abroad, and over 2000 throughout the United States.

RESIDENCE OF JOHN WALKER, LAKE AVE., CLEVELAND, O.

An idea of Mr. Walker's is for number-

ing in gear lists, which has been adopted by a large number of firms. Mr. Walker's plan is as follows :

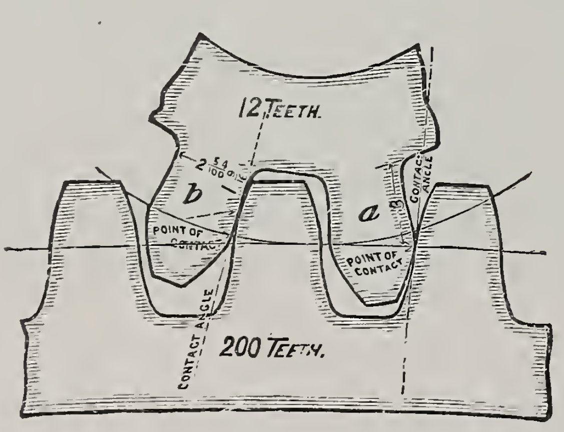
The figures preceding the final three figures given in a number indicate the pitch in eighths of an inch, while the



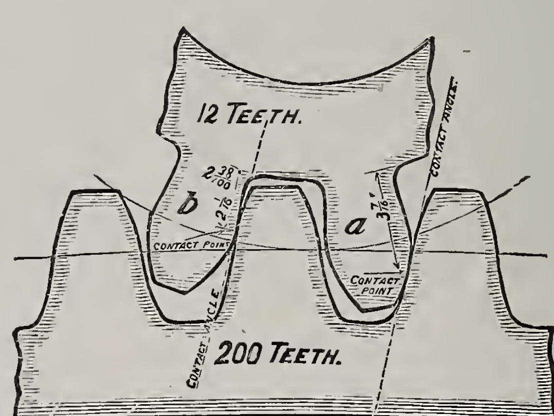
WALKER'S PATENT GEAR SCALE.

three last figures represent number of teeth. For example :

Spur gear 20040 signifies that it is 2½ inches pitch and 40 teeth. The importance of this systematic scheme for numerically tabulating all sizes of gears can only be fully appreciated by those who have gone through the drudgery of storing and listing gear patterns in a large foundry.



WALKER.

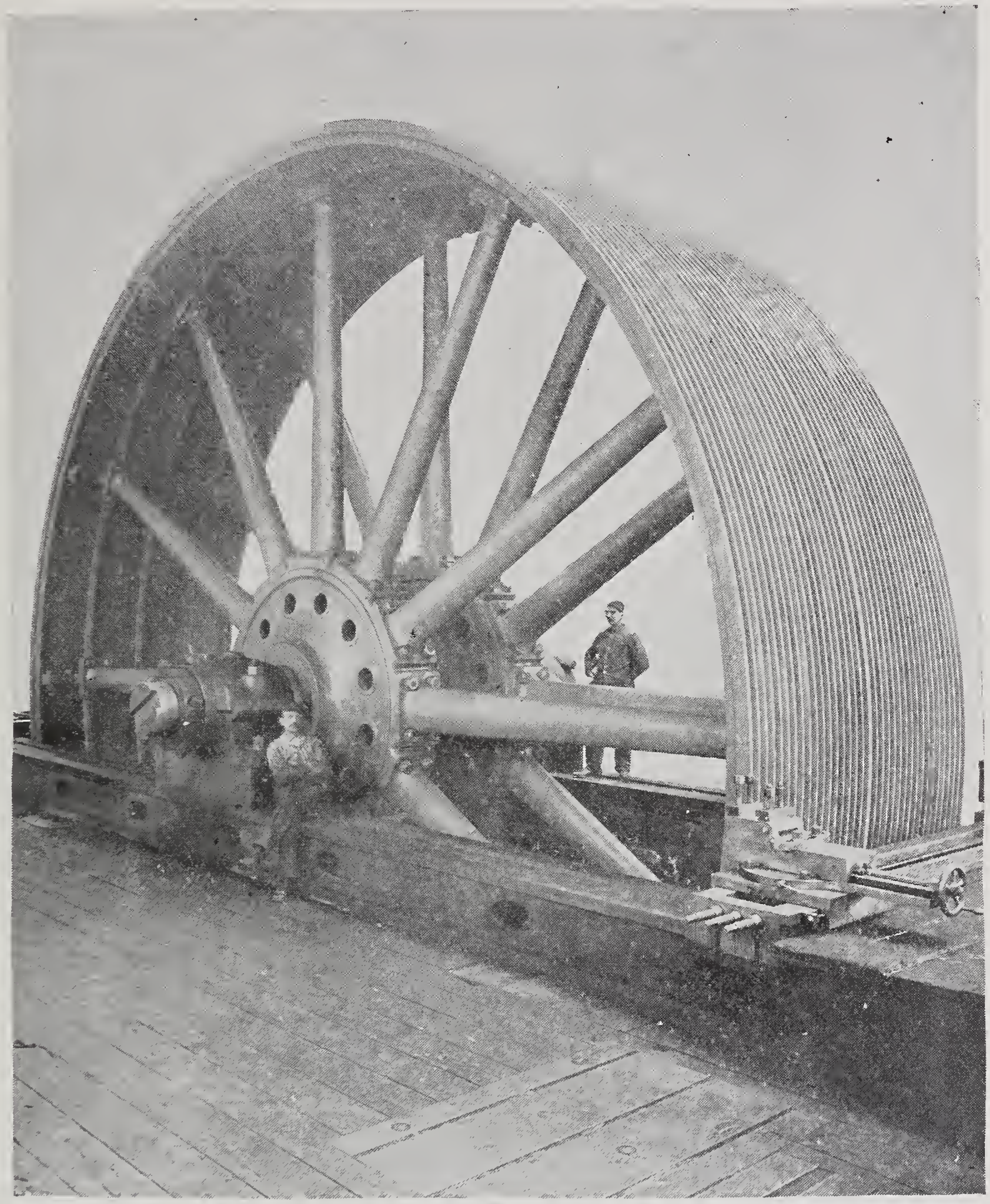


WILLIS.

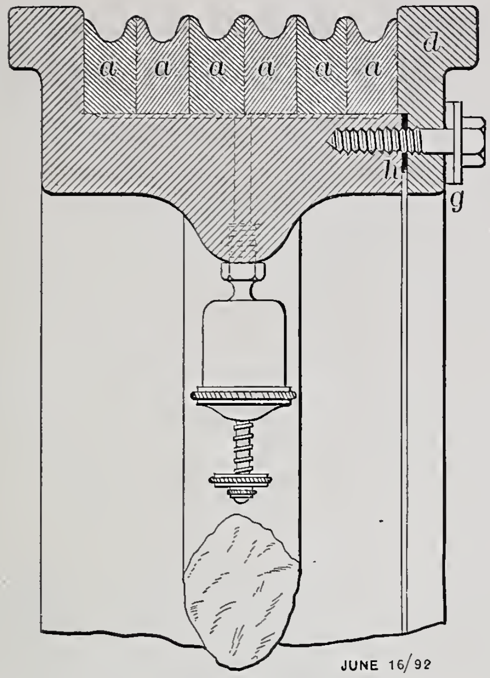
During the ten years following the invention of the gear scale, Mr. Walker went through the experience many leading American engineers have had, of moving about from place to place,—an experience which did as much, if not more, for Mr. Walker than it has done for others. It broadened his ideas and increased his ability. During these ten years he was successively connected with Wm. Wright, of Newburgh, N. Y., Poole & Hunt, of Baltimore, and for several years before the organization of the Walker Manufacturing Company with the Nordyke & Marmon Company, at Indianapolis. It was at this latter establishment that many ideas now in use in Mr. Walker's establishment are to be seen. Patents granted him from 1880–82 were for shaft couplings, molding machines, gear molding machines, traveling cranes, and other things.

In 1882 he determined to organize a company for the manufacture of specialties under his own patent rights, and men of wealth, like J. B. Perkins, Esq., the popular millionaire of Cleveland ; General Leggett, Commissioner of Pat-

ents under Grant ; Ex-Mayor Gardener, H. T. Taylor, Esq., T. Kilpatrick, Esq., and others, came to his aid. On the 20th day of September, 1882, was founded on the southern shore of Lake Erie the Walker Manufacturing Company, a firm which in less than ten years has grown into one of the greatest engineering concerns in the United States. Under the capable management of John Walker, assisted by Mr. W. H. Bone and staff, the reputation of this company for high-class work, in the form of machine molded gearing, pulleys, traveling cranes, and cable machinery, etc., rapidly spread. All this time his active inventive faculties were in full play, and up to the year of 1888 his patents had risen to twenty-five, when a great impetus was given to the industry on lake



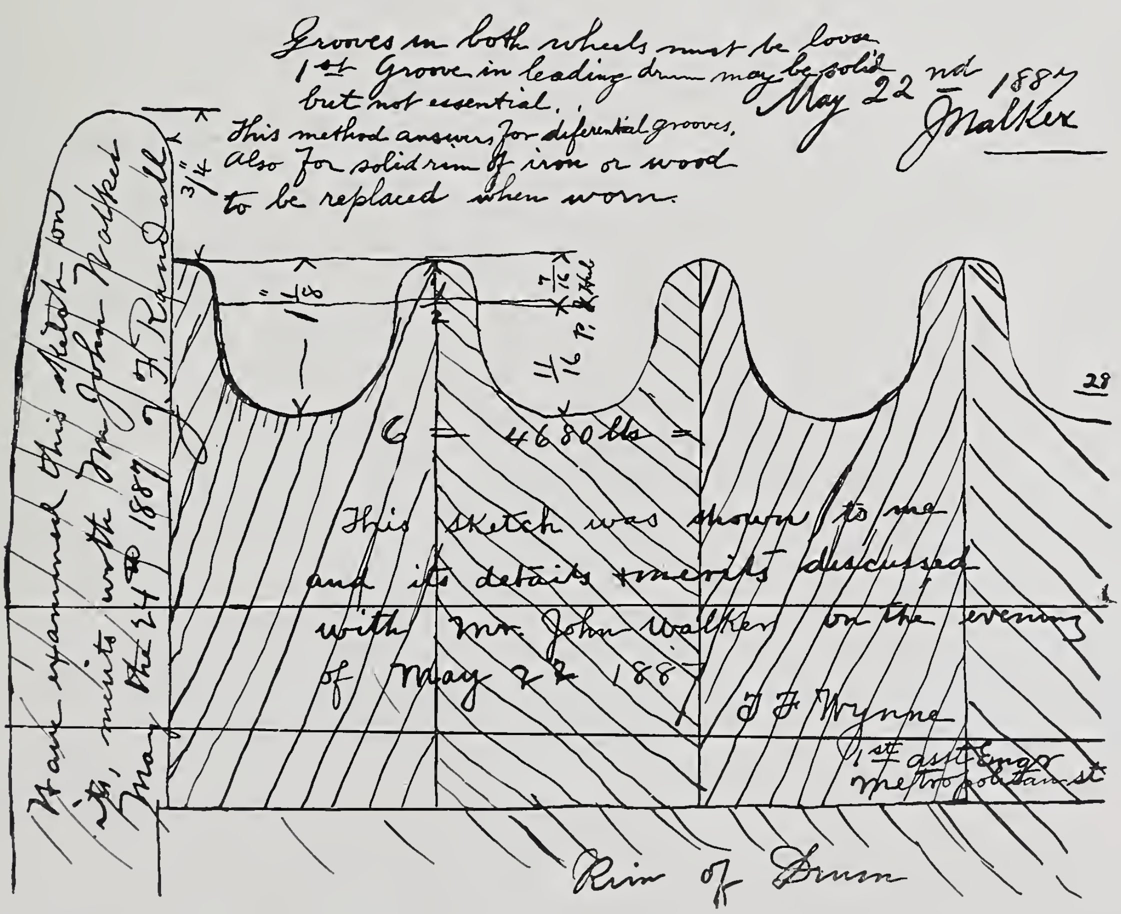
A LARGE DRUM.



SECTION OF WALKER'S PATENT DIFFERENTIAL CABLE DRUM.

shore by the invention of his famous differential cable drum. Of such utility did this unique mechanical device without introducing the differential drums, and since the Walker Manufacturing Company had a monopoly, they almost invariably succeeded in securing the contract for the whole cable machinery. So great was the influx of business that the existing plant was found to be utterly inadequate to meet the demand. Hence in 1891 was built, in accordance with the ideas and under the supervision of Mr. Walker, what has been described by competent authorities as the finest machine shop and foundry on the continent of America.

The machine shop, of which the illustration is a part section, is built in three bays, each 57 feet wide, two being 288 feet and the third 430 feet long, with provision to extend to 500 feet. Each bay is provided with a 30-ton traveling crane and fitted with the latest and most modern appliances for drilling, milling, turning, boring, planing every description of machinery from a ¼-inch bolt to

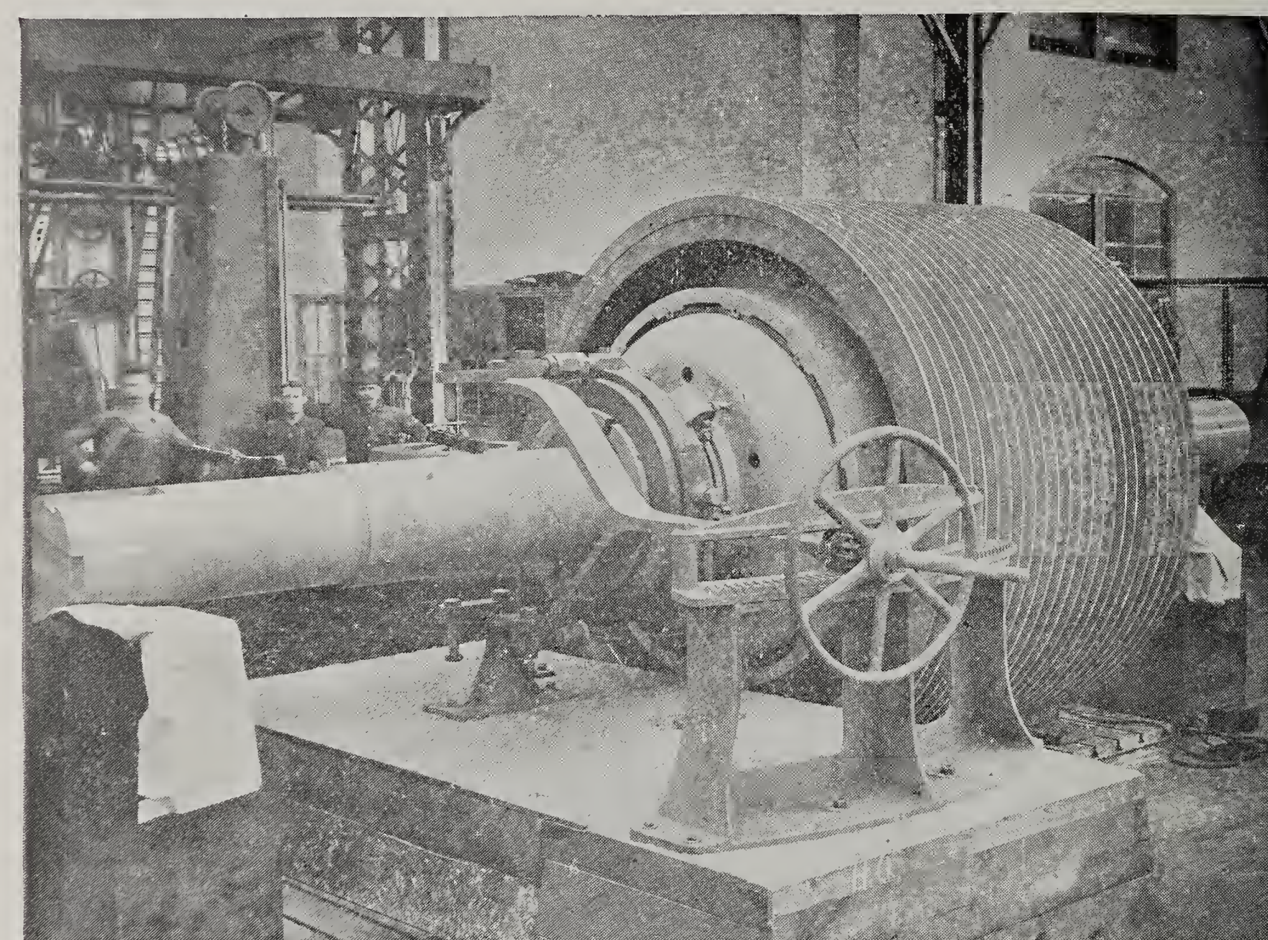


FROM ORIGINAL SKETCH OF WALKER'S DIFFERENTIAL DRUM.

prove to be that no competent engineer to-day with an eye to economy in power and material dare design a cable plant massive structures like the great gear wheel recently shipped to the diamond fields of South Africa, colossal rope

drums like the four just made for the Broadway cable railway, New York, and massive friction clutches of 1000 horse-power for the same plant.

The main foundry, which was described by the *Machine Moulders' Journal*, in December last, as "America's model machinery foundry," is 118 feet wide by 300 feet long, and equipped with the best modern machinery known in the art of iron founding. At every turn in this immense establishment one comes across one or other of the labor-saving inventions of John Walker; indeed, it is one of the remarkable features of this man's genius that his patents are nearly all of practical application, whether it be cupola, friction clutch, shaft coupling, hanger pulley, traveling cranes, gear molding machines, power-transmitting device for cable railways, gear scale, or differential drums. To adequately describe all the products of his fertile intellect would extend this article far beyond the limits of a magazine. It only remains, therefore, to say a word about the most popular of all his inventions,—viz., the differential cable drum, and then we must leave the story of John Walker and his work to the memory of all who are interested.

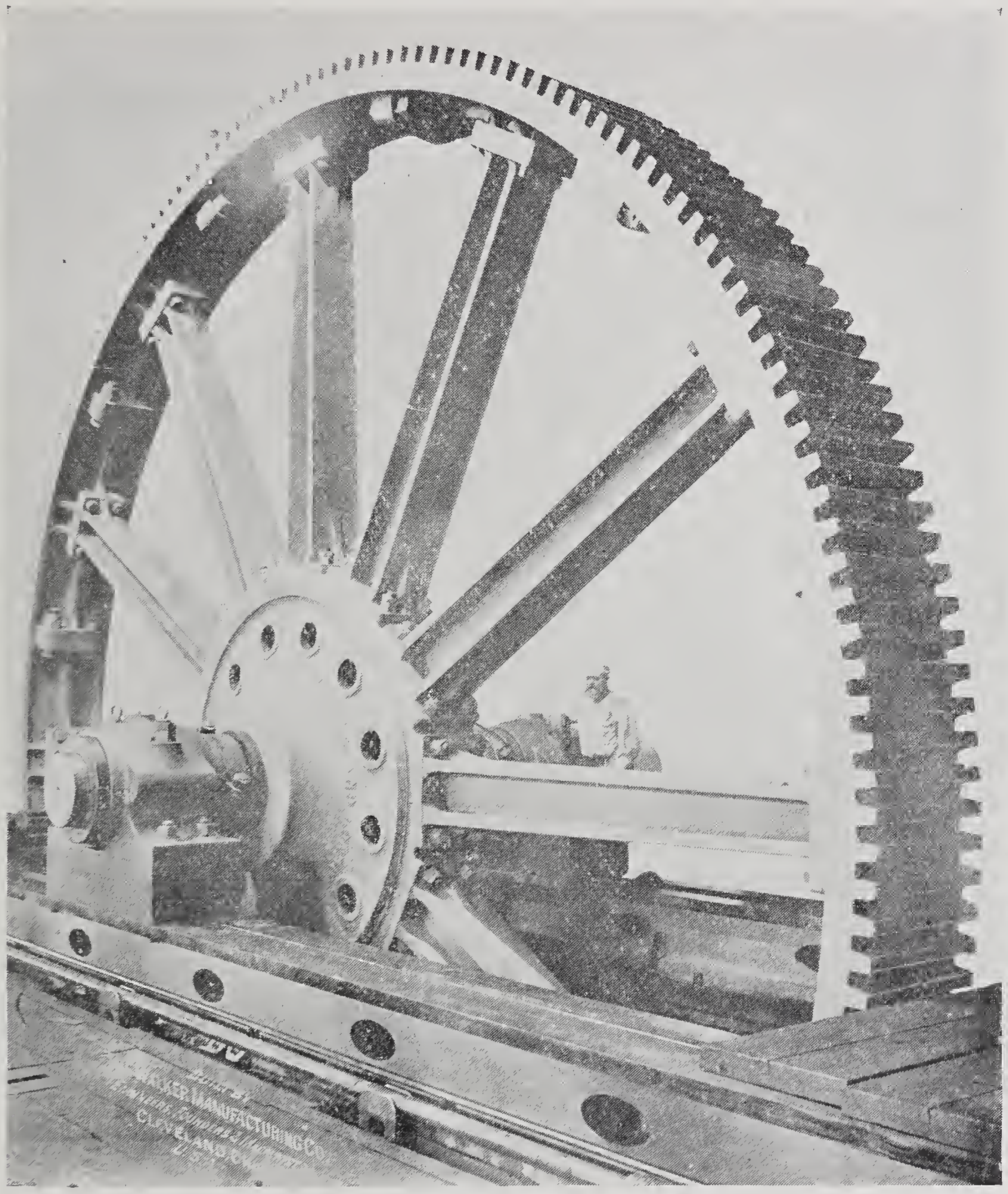


1000 HORSE-POWER FRICTION CLUTCH.

The Walker differential drum is not only extensively used in cable railways, but is coming into use for haulage in mines. In the Journal of Federated Institution of Mining Engineers of England, for September, 1891, is a description by Mr. H. W. Hughes, mining engineer to the Earl of Dudley, of a pair ot these drums, which are working successfully in the Bell End pit, Staffordshire, England. After setting forth the deplorable wear and tear of the old-fashioned solid drum grooves and cables, Mr. Hughes goes on to say: "The Walker differential pulley adopted at the Bell End pit completely gets over these difficulties."

Briefly described, it consists of a series of loose rings, placed (*a*) on an ordinary pulley, these rings being grooved to receive the rope. The

flange (*d*) on one side of the pulley is removable and secured in position by a series of bolts, (*e*) india-rubber washers being provided (*g* and *n*) to prevent the bolts becoming loose during working. Both pulleys have loose rings, and both are driven, the second pulley all the grooves are loose. At first sight it would be thought that at least one fixed groove should be provided, so that the requisite grip may be obtained, but this is not necessary. The explanation appears to be that the pressure of the rope on the groove of each individual



A LARGE GEAR WHEEL.

having one groove less than the first. The hub of each pulley is central with the other, as the different number of grooves gives the necessary offset to equalize the angling of the rope as it travels from one to the other.

The peculiar point about them is that ring is transferred to the under side of the ring, and that the friction is just as great on the under side of the ring as it would be under the rope if the pulley had solid grooves.

"Each ring adjusts itself to the unequal strain on the rope or wear in the

groove, and constantly accommodates itself to these conditions whilst in motion. The fact that the ropes equalize themselves on the ridge gives each wrap its proportion of duty, so that there is no necessity to secure any of the grooves. It is essentially a friction drive, with each ring accommodating itself as described. The rope never moves on the grooves, as is proven by the fact that, when at work, the impression of the rope is left in the oil on the bottom of the rings, which conclusively shows that no slipping takes place." By the use of these drums on cable railways the lives of steel cables have been increased from 6 to 20 months, and a saving of horse-power at the engine of over 37 per cent. In view of startling facts like these in the economy of power and material, it is not to be wondered at that, during the last five years, the Walker Manufacturing Company have made 116 of these differential drums, 30 of which have displaced solid drums, and they have 48 on the books now, four of which go to Sydney, Australia.

Such, briefly, is an outline of the career and inventions of a man who is a high type of thousands of Englishmen who have found in America a splendid field for talent and real worth. Mr. Walker is even now only 45 years of age, robust in health, and intellectually as active as ever. He is a member of the Engineers' Club of New York, American Society of Mechanical Engineers, and Civil Engineers' Club of Cleveland, Ohio.

SECTION OF MACHINE SHOP OF THE WALKER MANUFACTURING COMPANY, CLEVELAND, O.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS.

THE last meeting of the National Association was the most successful one ever held, and demonstrated very conclusively the great work this association is accomplishing.

On the next page is printed an engraving of the newly elected president, Mr. C. W. Naylor. The *Stationary Engineer*, of Chicago, some time ago, printed an article about Mr. Naylor, and it is from that publication the following biographical sketch has been taken:

Mr. Naylor was born at Leeds, England, in 1858. Being, as he says, of a restless disposition, he emigrated to this country as soon as he was able to walk, and brought his parents with him. Coming as he did before he was a year old, he claims that he is fairly entitled to be considered an American. He is the eldest of four children. Mr. Naylor's father is a veteran engineer, having followed the trade for upward of fifty years. Realizing the importance to the engineer of a thorough education, he spared neither money or labor to fit his son to occupy the highest position in the trade which he has chosen for his calling.

Until his ninth year young Naylor lived in Southern Illinois. In 1868 he came to Chicago and entered the public schools of that city, continuing therein until he graduated with high honors from the Central High School, in 1876, being a prize member of the famous "Centennial" class of that year. Here he laid the foundation for a very thorough technical education, becoming most proficient in mathematics, natural philosophy, and mechanical drawing. During the three months' vacation of each school year he was put at work in the shop, spending thus six months in the Keystone Foundry & Machine Works, and subsequently eight months with Agnew & DeWolf, founders and machinists. After this Mr. Naylor entered the employ of the Crane Bros. Manufacturing Company, serving nearly three years in their extensive shops, building and erecting engines, ice machines, and elevators. While thus employed he spent his evenings in the study of mechanical drawing under the special instruction of Professor Van der Raillen, now at the head of the California State Polytechnic Institute.

After leaving the machine shop Mr. Naylor completed a course of two full years of study in the scientific department of the old University of Chicago. In 1881 he entered the employ of the Illinois Central Railroad, and had a position under the chief engineer of the southern division, with headquarters at Jackson, Tenn. He spent the fall and early winter engaged in surveys in Kentucky, Tennessee, and Mississippi.

While thus engaged in the Yazoo bottoms he was taken with a violent fever, and after two months' siege recovered and returned to the north, having been cured of any desire for further roughing it in the south.

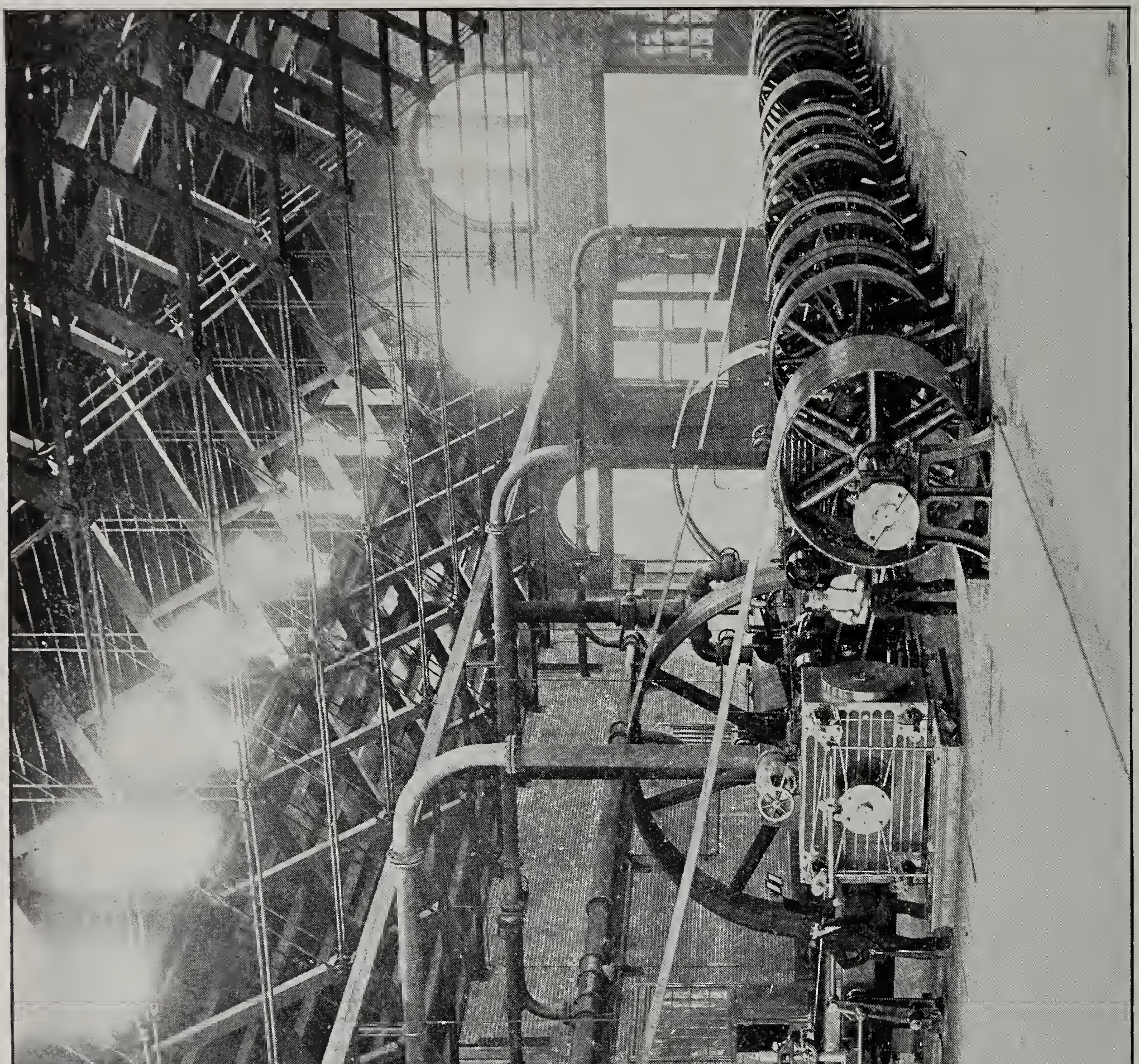
Mr. Naylor served a short time under his father, who was then chief engineer for the old firm of Field & Leiter, and then entered upon a term of four years of service with the Hay & Prentice Company, where he gained a thorough knowledge of steam heating and ventilating. For the past five years he has filled the position of first assistant engineer of the immense establishments of Marshall Field & Co. This position he now holds, and of which he is justly proud.

As may easily be seen, Mr. Naylor's success in his trade has been largely promoted by his thorough education in all matters pertaining thereto, both theoretical and practical. He has been largely aided in obtaining this education by the assistance and practical experience of his father, with whom he is now associated, and under whose orders he now works. The advantages to be derived from a thorough education are

CHARLES W. NAYLOR.

well exemplified in his case, and his present position shows what comes of "brains in the engine room."

Mr. Naylor is a popular member of Chicago No. 28, N. A. S. E., and contributes largely to the educational success of his association, being always ready to impart from his store of knowledge to help others. He is a fluent talker, has written some for different mechanical papers, and is active in promoting the educational advancement of the operative engineer. Gentlemanly in all things, respected and loved by those who work under him, enjoying the confidence and esteem of his employers, he is a good example of what the working engineer can make of himself when he has the will to study.



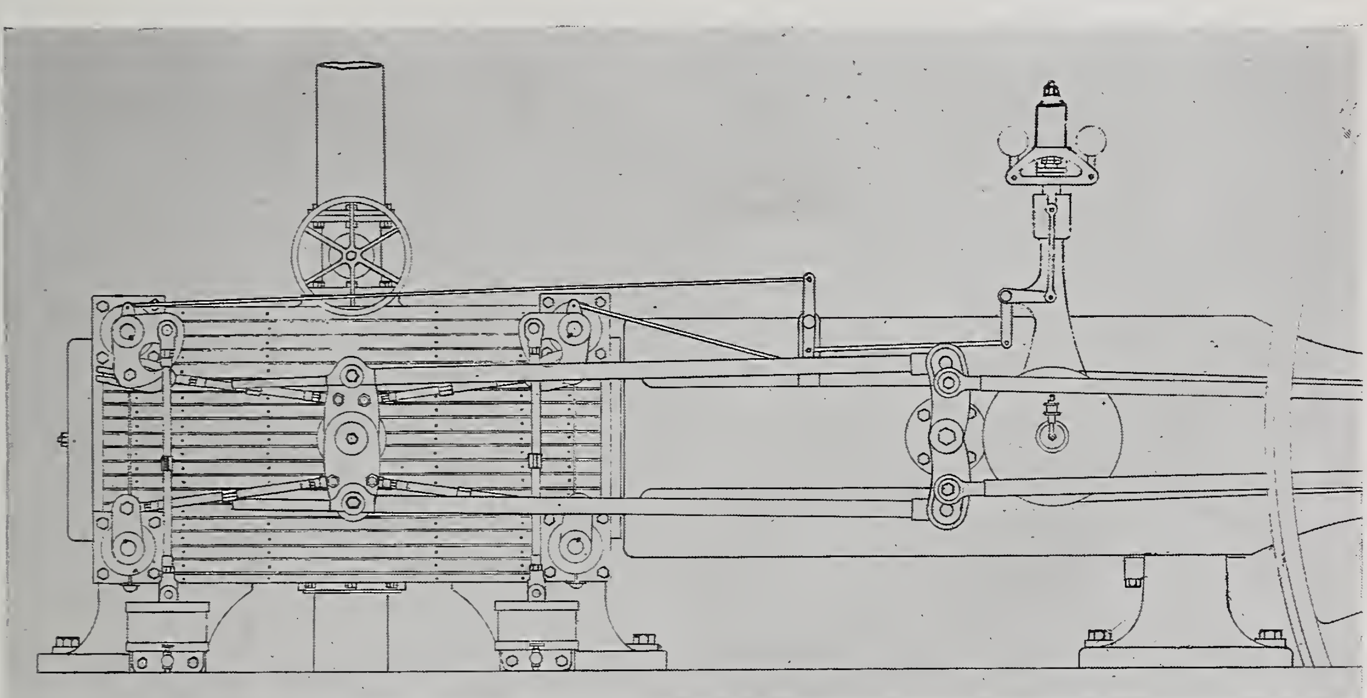
HUNT STREET GENERATING STATION OF THE CINCINNATI STREET RAILWAY CO. CORLISS ENGINES BUILT BY THE LANE & BODLEY COMPANY.

A NEW STREET RAILWAY PLANT.

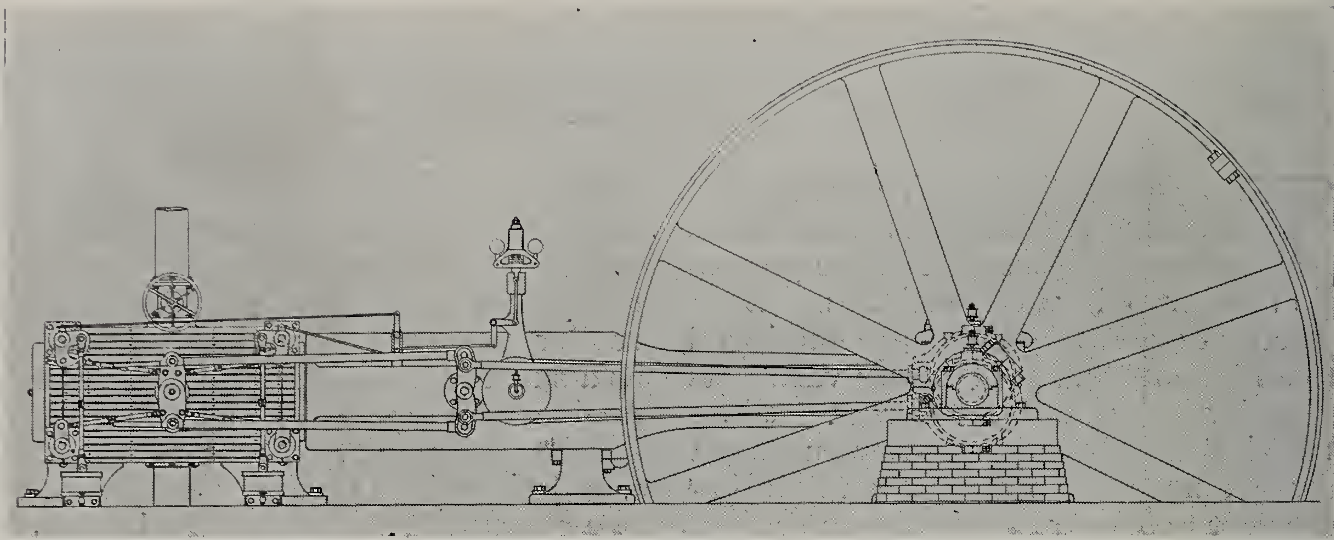
THE city of Cincinnati, as compared with other cities of its class, ranks among the foremost in the possession of rapid-transit facilities. Both electricity and the cable are employed to an extent worthy of a city vastly its superior in size and population. Since 1886 it has built and profitably sustained three long cable systems, and during the past two years some five new lines of road have been equipped with electricity.

The Hunt Street Station of the Cincinnati Passenger Railway Company, an illustration of which is printed on the opposite page, was equipped by the Lane & Bodley Company of that city. The steam plant consists of three single, high-pressure, non-condensing Corliss engines, two of which have cylinders 28 inches bore and 60 inches stroke; main shaft, 14 inches diameter, 12 feet long; fly-wheel pulleys, 22 feet diameter, with faces for 48-inch belt; weight, 40,000 pounds each. The third engine has 24-inch cylinder, 60-inch stroke, 12-inch main shaft; pulley, 20 feet diameter, 48-inch face; weight, 36,000 pounds. In all, about 1200 rated horsepower.

With a view of obtaining a better distribution of load under the varying conditions met in street railway operation, these sizes were adopted, and to render the 24-inch engine serviceable as a substitute for either of the 28-inch engines, in case of emergency, a special double-valve gear throughout was designed. On the main shaft are two eccentrics, one connected by means of the usual (but modified) rocker and wrist plate with the steam, and the other with the exhaust valves, thus enabling the limit of cut-off to be extended to three-quarter stroke, and the power developed to approximate that of the larger engines. While the double-eccentric Corliss valve motion is not novel, it has in this instance been simplified and very neatly and symetrically worked out, as illustrated in above cut, in which is shown the method of operating the two rocker arms from the same central stud, which avoids the rocker-arm hanger used even with single-valve gears, and the same idea carried out in case of the double wrist plate, using the usual central stud on which both wrist plates vibrate, produces an arrangement which in appearance and in operation



VALVE GEAR OF DOUBLE-ECCENTRIC CORLISS ENGINE BUILT BY THE LANE & BODLEY CO.



SIDE ELEVATION OF ENGINE.

seems to leave nothing to be desired in this direction. The main receivers are 70 inches diameter, 48 inches face, on 8-inch jack-shaft, and all the rest of the shafting is 6 inches and 7 inches diameter. The boiler house is 130 x 48 feet, and contains three Babcock and Willcox boilers of 400 horse-power, each fed by two 8 x 6 x 12 inch duplex steam pumps of McGowan make. Two Hoppes heaters of 300 horse-power each supply the feed water, and the whole is connected by an entirely duplicate system of steam piping. A brick chimney 8 x 150 feet completes the boiler equipment. The elecricity is supplied by 16 generators of 80 horse-power each.

PLATE-EDGE PLANING MACHINE.

A SPECIALLY designed plate-edge planing machine has recently been constructed by Messrs. Cunliffe & Croom, of the Broughton Iron Works, Manchester. This machine is arranged to admit plates of any length, and plane sixteen feet at one stroke with a turn-over tool box to cut both ways. It is built on a strong bed, with broad wearing surface for the headstock to travel upon, this bed being twenty feet long; and to it is cast the table upon which rest the plates, while extension brackets, with anti-friction rollers, are provided, to take any width of plates. The housings, which are of the box pattern, are bolted to the ends of the bed.

The cramping girder is of wrought iron, box section, twenty-one feet eight inches long, and twenty-six inches deep in the middle, fixed to the housings by bolts, the face of these housings being specially prepared with recess to sustain the upward pressure. The cramping screws are made of steel, with hard points set eighteen inches apart. A lock nut is attached to each cramping screw to keep it down to its work, every screw being so arranged that it can be reached from the ground when cramping or uncramping the plates. The headstock carrying the tool box is provided with incline stops to reverse the direction of the travel at any part of the stroke, or at full stroke, and at the same time the tool box is turned over automatically, and a cut put on vertically, the adjustment for setting in the tool for depth being operated by hand from the front. A platform is attached to the traveling carriage to carry the attendant and enable him to control the machine while running. The head is driven by a steel screw 3½ inches in diameter gearing into a gunmetal nut. The method of driving can be arranged either as shown or at right angles to the bed, to suit the user's convenience. The accompanying illustration is taken from *The Engineer*, London.

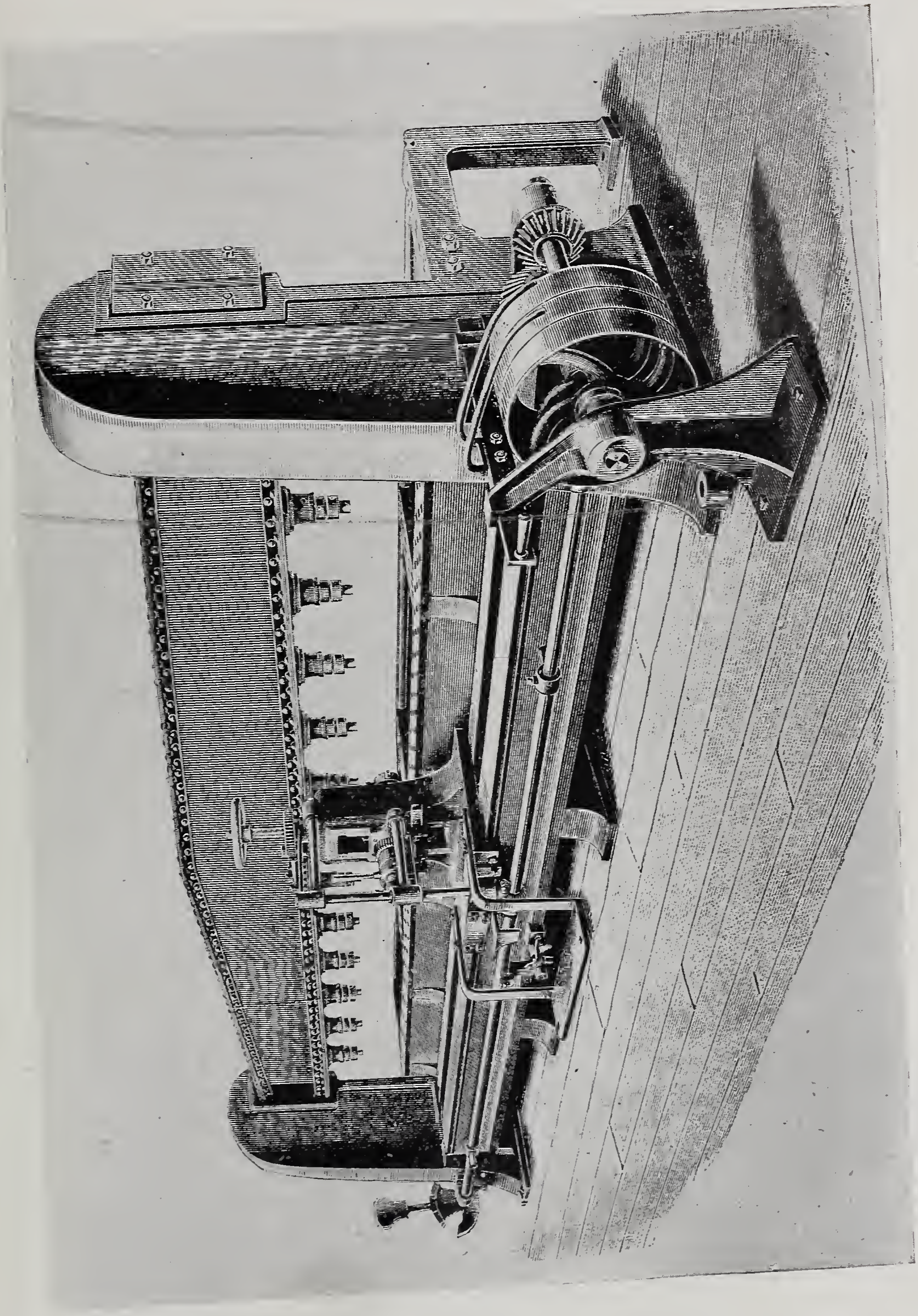
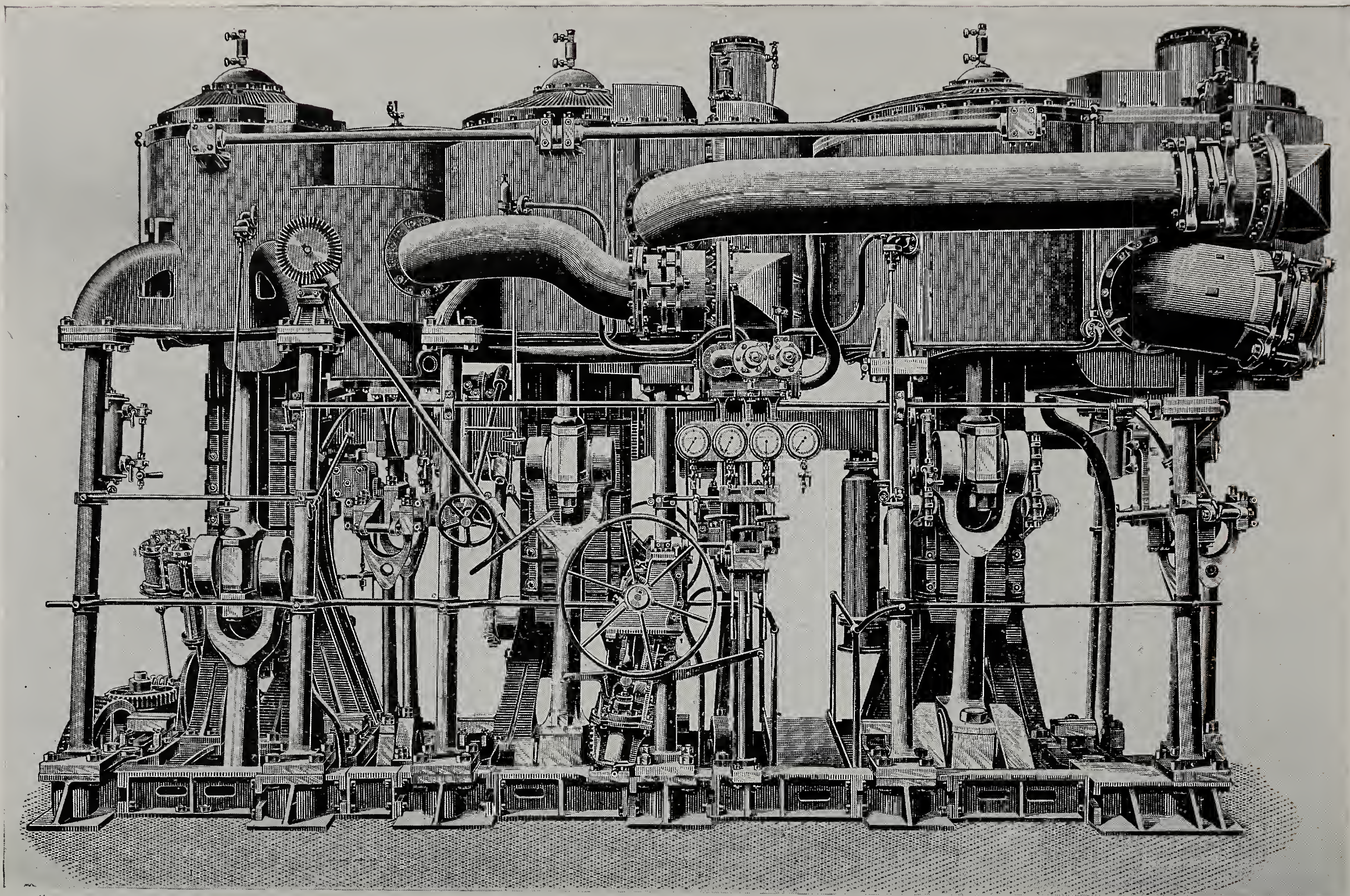


PLATE-EDGE PLANING MACHINE BUILT BY MESSRS. CUNLIFFE & CROOM, MANCHESTER, ENG.



FROM "ENGINEERING," LONDON.

TRIPLE-EXPANSION ENGINES OF H. M. S. S. "INDEFATIGABLE," "IPHIGENIA," AND "INTREPID," CONSTRUCTED BY THE LONDON AND GLASGOW ENGINEERING AND IRON SHIP-BUILDING CO., LIMITED, GLASGOW.

NEW MARINE ENGINES.

THE two illustrations of triple-expansion engines herewith presented represent the propelling machinery of three new English cruisers, the *Indefatigable*, *Iphigenia*, and *Intrepid*. The dimensions of these vessels are: Length, 300 feet; beam, 43 feet 8 inches; displacement at 17 feet 6 inches; draught, 3600 tons.

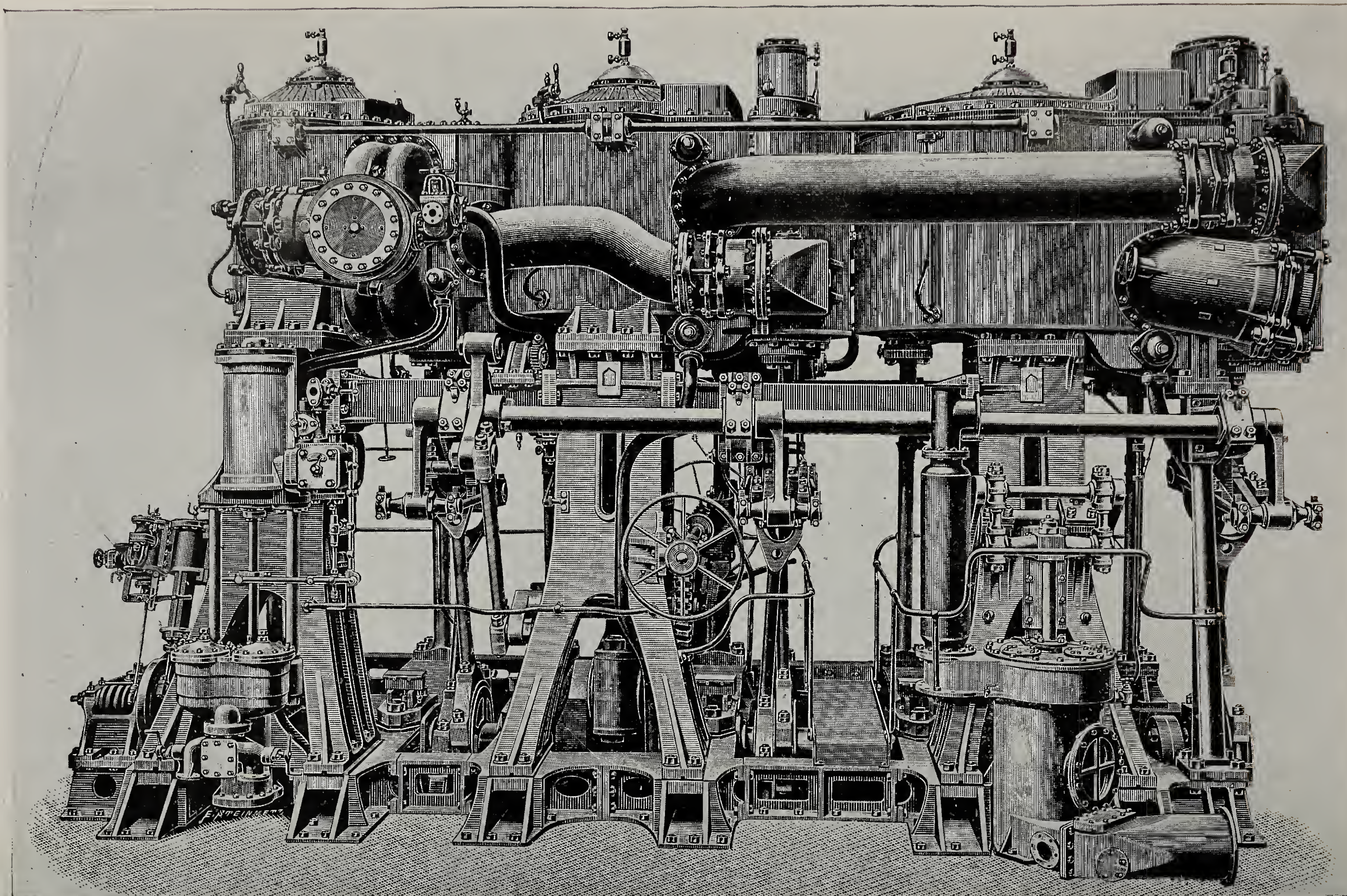
The machinery consists of two sets of triple-expansion engines driving twin screws, and was designed to indicate 9000 horse-power at 140 revolutions. The engine rooms are divided by a fore-and-aft water-tight bulkhead. The engines are of the usual inverted three-crank type, having cylinders 33½ inches, 49 inches, and 74 inches in diameter, with a stroke of 39 inches, all steam-jacketed. To insure lightness combined with strength the engines are constructed of steel and gun metal where practicable. The liners of the high-pressure and intermediate cylinders are of forged steel, and the low pressure of cast iron. The high-pressure cylinder is fitted with a piston valve, the other two with ordinary slide valves, the low-pressure slide valve relief frame and balance cylinders being Mr. John Thom's patent. All valves are driven by ordinary eccentrics. A double-cylinder starting and reversing engine is fitted, and also a hand and steam turning gear for overhauling the main engine.

There is one single-acting vertical air pump 24 inches in diameter by 18 inches stroke to each set of main engines worked from the low-pressure crosshead. The main condensers, which are placed athwartship, are 6 feet 2 inches in diameter, and 7 feet 10 inches between the tube plates. The shells are of $\frac{5}{16}$-inch rolled brass plates with butt-strap joints. Each condenser contains 4112 tubes $\frac{5}{8}$ inch external diameter by No. 18 I.W.G. thick, giving a total cooling surface of 10,540 square feet for both condensers. Two of Drysdale's 14-inch centrifugal pumping engines are fitted for circulating the water through the condensers. They are arranged to draw from the bilge when required, and each pump is capable of discharging 750 tons of water per hour. In addition to the main condensers, there is also fitted in each engine room an auxiliary condenser with air and circulating pumps for dealing with the exhaust steam from the various auxiliary engines throughout the ship.

The main feed pumps are placed one in each engine room. Fresh water is supplied by two evaporators by the same firm in conjunction with Normandy's distillers. The fire and bilge engines, air-compressing engines, electric-light engines, and dynamos, all in duplicate, are suitably arranged in the engine rooms.

The shafting is of hollow steel throughout, the crank shaft is 12¾ inches in diameter at the bearings, the crank pins 13¼ inches in diameter by 15 inches long, and the propeller shaft is 12¾ inches and 14½ inches in diameter, in one piece 50 feet long. The propellers are 13 feet in diameter by 17 feet 6 inches pitch. Each has three blades, and the expanded surface of each propeller is 40 square feet. The boss is spherical, and the blades are fixed by naval brass pins, finished with cover plates. The boss and blades are of gun metal.

Steam is supplied by three double-ended boilers 13 feet in diameter by 18 feet 6 inches long, and two single-ended boilers 13 feet diameter by 9 feet 6 inches long, constructed for a working pressure of 155 pounds per square inch. One of the single-ended boilers is used for electric light and for turning the main engines, etc., when in port. There are three corrugated furnaces, 3 feet 6 inches mean internal diameter, in each end of the double-ended boilers, or 24 furnaces in all, with a separate combustion chamber for each furnace. The total heating surface in the five boilers is 15,888 square feet, and the



FROM "ENGINEERING," LONDON.

TRIPLE-EXPANSION ENGINES OF H. M. S. S. "INDEFATIGABLE," "IPHIGENIA," AND "INTREPID."

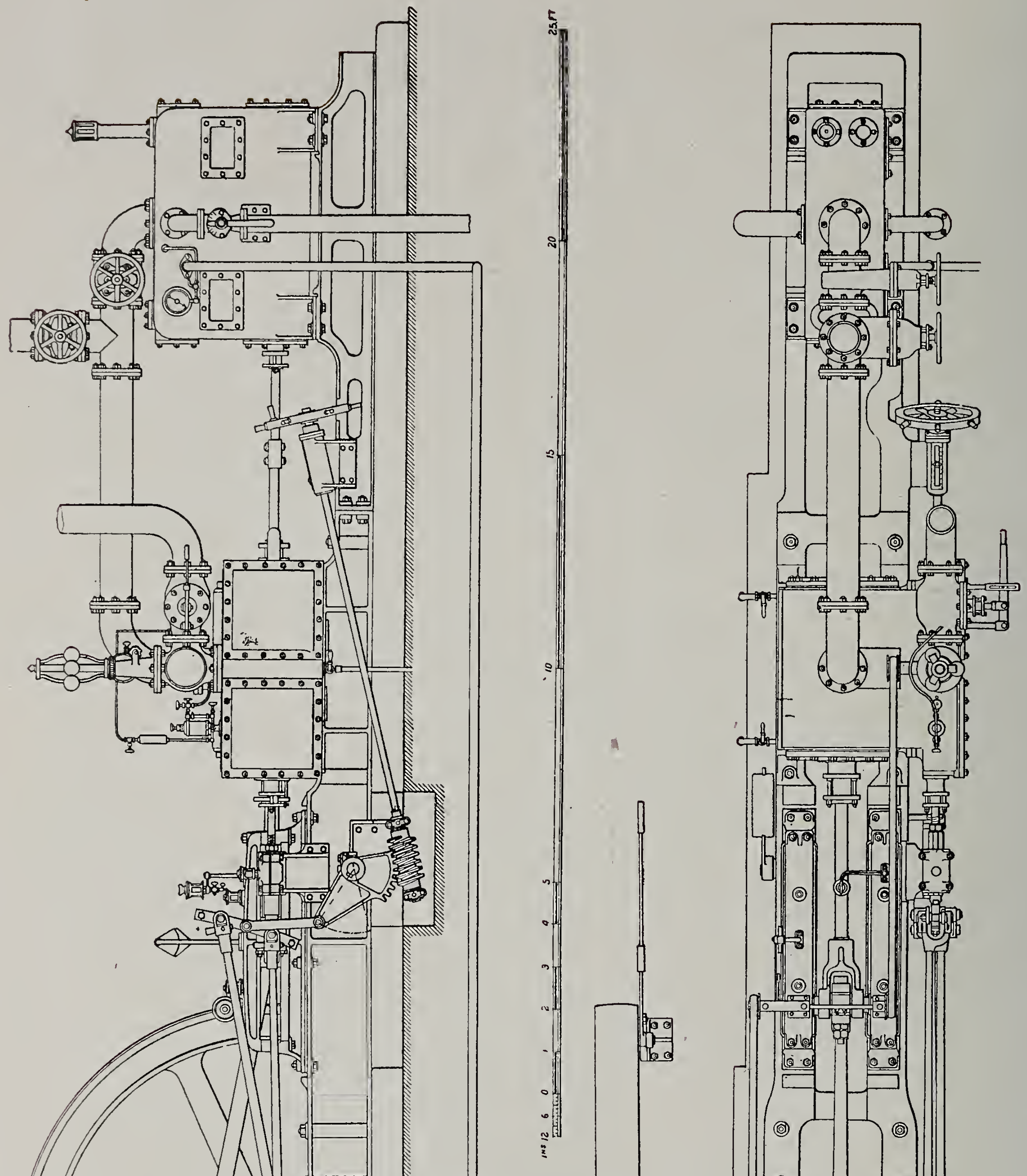
grate surface 595 square feet. The two boiler rooms have a water-tight bulkhead between them athwartship, and they are arranged for forced draught with closed stokeholds. Air is supplied to the furnaces by eight fans placed below the protective deck. Each is driven by a small vertical engine of the ordinary type. Two steam ash-hoisting engines are fitted, and efficient means provided for handling the ash buckets with the stokeholds under pressure, while with natural draught and open stokeholds the arrangements are such that a plentiful supply of air is available. The double bottom under the boiler rooms is used as a fresh-water reserve tank, with appliances for filling from ship's side or from upper deck. Three double-cylinder auxiliary feed engines are placed in the stokeholds, and are arranged to draw from the reserve tanks, sea, main condensers, and feed tanks. The main steam pipes have received careful attention, the straight lengths above 8 inches in diameter being of copper with brazed joints served with copper wire under tension. The pipes under 8 inches in diameter are of solid drawn copper, the flanges being thick and substantial with close bolting and recessed joints, and the bends of strong gun-metal castings, all efficiently stayed by round steel tie-rods. Provision is made for expansion by stuffing boxes in suitable positions.

Above the protective deck is a workshop fitted up with lathes, shaping machines, etc., complete, with a vertical engine for driving the various machines. Altogether there are in one vessel 39 separate steam engines requiring the supervision of the engineer in charge.

The trials of the engines have been most successful, both under natural and forced draught, all the machinery working smoothly and satisfactorily. We append the detailed results of the trials of the first of the three vessels. The machinery on this occasion, it may be stated, was under the charge of Mr. William Morison, manager of the engine works of the London and Glasgow Company.

RESULTS OF TRIALS OF H. M. S. "INDEFATIGABLE" OFF ISLE OF WIGHT.

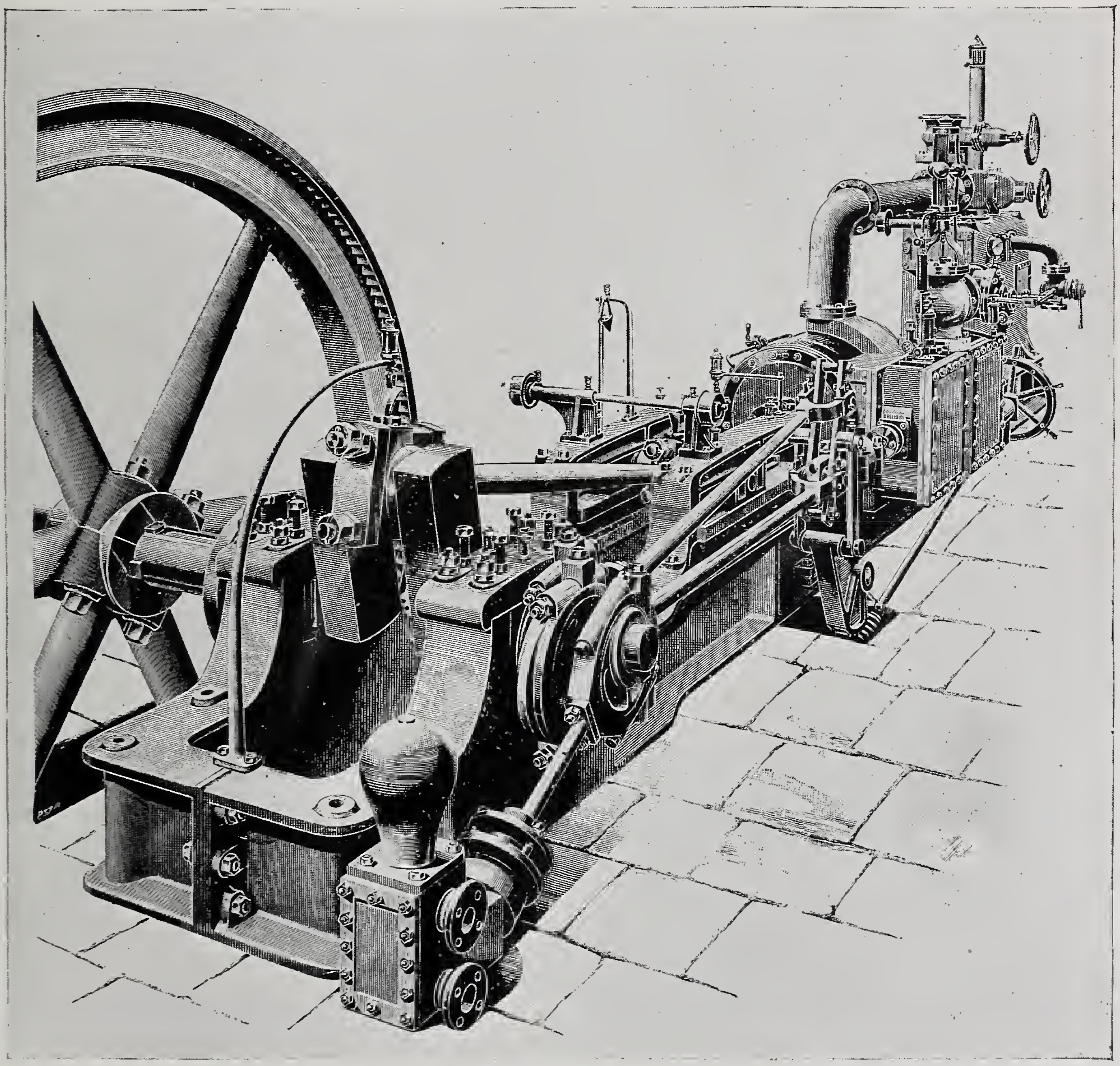
	Natural Draught.		Forced Draught.	
Draught of water	Forward, 15 feet. Aft, 18 feet 6 inches.		Forward, 15 feet. Aft, 18 feet 6 inches.	
Steam in boilers	134.7 pounds per square inch.		135.9 pounds.	
	Starboard Engine.	Port Engine.	Starboard Engine.	Port Engine.
Vacuum	27	26.9	25.46	26
Revolutions per minute	126.3	127.5	136.9	138.1
Mean pressure — High	48.28	44.7	49.66	50.27
Mean pressure — Intermediate	27.05	26.78	31.73	31.73
Mean pressure — Low	12.82	12.6	14.65	14.45
Indicated horse-power — High	1059	989	1181	1232
Indicated horse-power — Intermediate	1270	1269	1614	1628
Indicated horse-power — Low	1373	1361	1699	1692
Total indicated horse-power	3702	3819	4494	4552
Collective indicated horse-power	7321		9046	
Mean air pressure	.47 inches		.92	
Speed of vessel	18.74 knots		19.75 by patent log	



HORIZONTAL ENGINE FOR DRIVING A ROLLING MILL, CONSTRUCTED BY HAYWARD, TYLER & CO., ENGINEERS, LONDON.

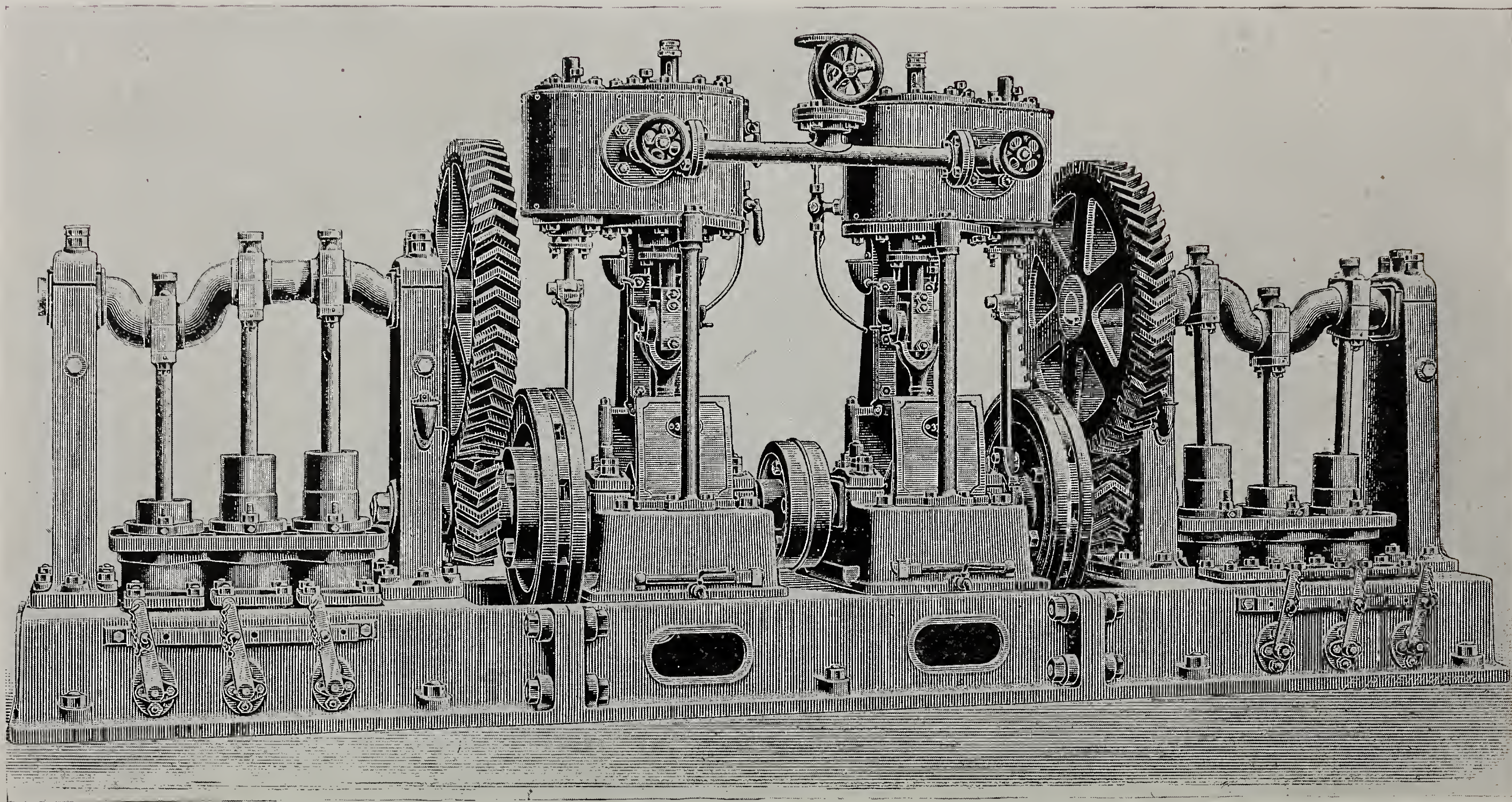
NEW ROLLING-MILL ENGINE.

THE illustration on this and the opposite page represents an engine with some novel features. The steam cylinder is 24 inches in diameter, the stroke being 36 inches. The usual steel, 8 inches in diameter in all bearings, made to a special analysis and tensile test. The engine, as will be seen, is fitted with ordinary link-motion reversing gear, driving plain slide valves.



HORIZONTAL ENGINE FOR ROLLING MILL, CONSTRUCTED BY HAYWARD, TYLER & CO., ENGINEERS, LONDON.

working speed is 70 revolutions, equal to a piston speed of 420 feet per minute. The fly-wheel is 12 feet in diameter, and weighs about 6 tons. The crank shaft, of double-web form, is of the best mild These latter are of the usual divided type, one-half at each end of the cylinder, to get short straight ports. Great care has been taken to have ample strength and wearing surface in all parts



NEW BOILER-FEEDING PUMPS, CONSTRUCTED FOR THE CITY OF LONDON ELECTRIC LIGHTING STATION BY THE BRUSH ELECTRICAL ENGINEERING CO., LIMITED, LONDON.

of the link motion. The link has the pins forged on solid, and is case-hardened. The valve rod is of steel, driving the valves by means of square bridles forged solid on the rod, so that there are no nuts or cotters to come loose inside the steam chest. Reversing is effected by hand by means of a star hand wheel, worm, and quadrant. The cylinder is cast separate from the steam chest, which latter is bolted to it, so that in case of wear of the valve face the whole chest can be easily renewed. This is a somewhat expensive method, but makes a good job, and is more reliable than loose valve faces. A separate hard cast-iron liner was forced into the cylinder by hydraulic pressure, and it may be interesting to know that this took just 40 tons to send it home. The speed of the engine is regulated by the well-known Pickering governor, working a double-beat throttle valve. The horizontal air pump and jet condenser are of a special type arranged for a high piston speed. The air-pump barrel is quite below the condenser, so that it is always charged with water. The water in the end chambers of the air pump simply rises and falls about five inches at each stroke, and this water, acting as a fluid plunger, displaces the air, and the condensation water forces it through the delivery valves, so that, although the piston speed is high, the speed of the rising and falling surface of the water is low, and there is no commotion in the pump. The vacuum obtained is quite equal to that in a vertical air pump. The air-pump valves are metallic, of special make. This engine was constructed by Hayward, Tyler & Co., engineers, London, Eng., and for the illustrations for this article we are indebted to *Engineering*, London.

BOILER-FEEDING PUMP.

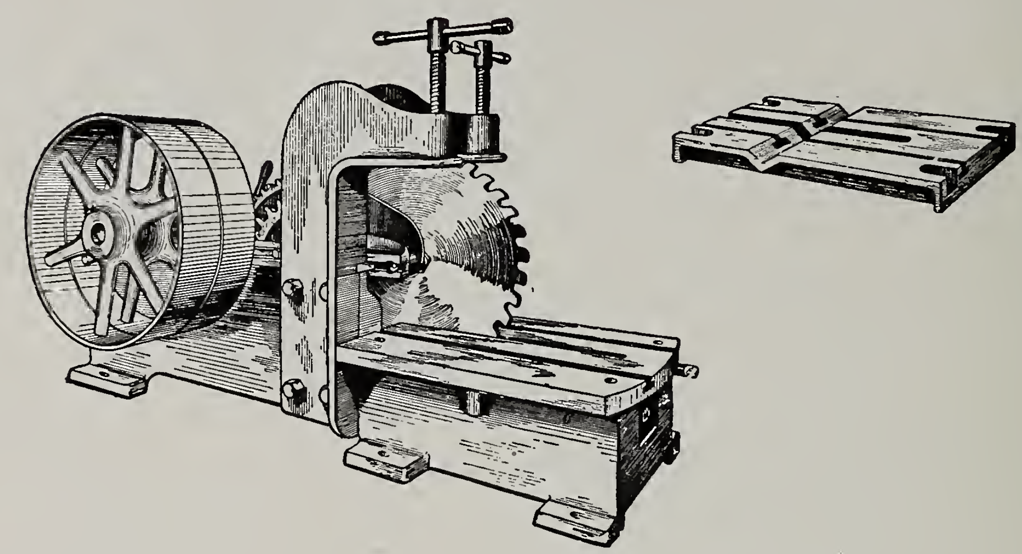
THE engraving on the opposite page shows a perspective view of a double set of three-throw pumps constructed by the Brush Electrical Engineering Company for the City of London Electric Lighting Company. There will eventually be seven sets of the same size, each half of which will feed boilers at 160 pounds pressure for 2000 indicated horse-power.

Each barrel is 5 inches in diameter by 5 inch stroke, and the steam cylinder is 7 inches in diameter by 6 inch stroke, geared 3 to 1. The engines are coupled by means of a bolted coupling with an intermediate plate, which can be readily removed in the event of the failure of either pump. The hand levers in front of the pump barrels are arranged to raise the suction valve of each barrel clear of its seat, so that any barrel may be thrown out of action at the option of the engineer. The valves are arranged with a water cistern, which reduces the noise in working, and each valve is accessible by removing one cover placed over the valve.

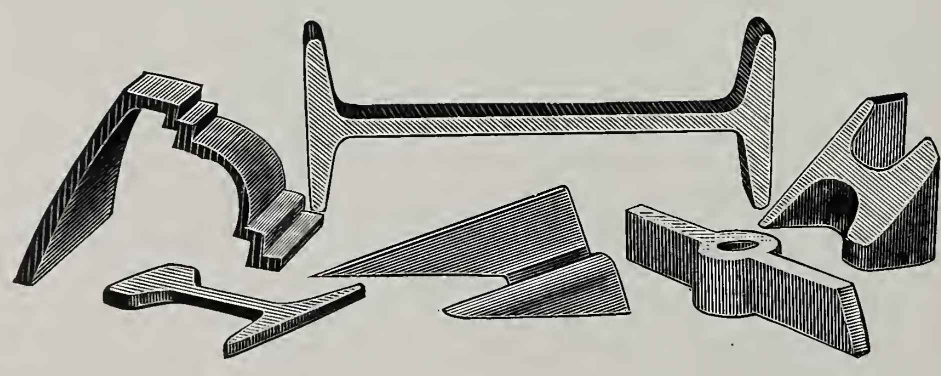
This pump was designed by Mr. J. S. Raworth, chief engineer of the Brush Company in England, with the object of reducing the waste of steam which is common to many commercial pumps. The driving engine is of the highest class made for electric-lighting purposes. His attention was called to the wastefulness of ordinary pumps in two instances when he used the exhaust steam from the pump to heat the feed valve; in both cases the feed water was raised to boiling point. By the substitution of the new pump, as illustrated, the temperature of the feed water is raised only 30 degrees, which demonstrates that the steam used by the new pump is not more than one-fifth of that used by the pump with which it was compared.

COLD-CUTTING METAL-SAWING MACHINE.

THERE was a time when a force of five or six men was required to cut off a steel railroad rail within half an hour, and, by laborious work, one man could cut from six to eight fifteen-inch "I" beams on an angle cut per day. Improvement in methods and time was sought, and the problem of decreased time and expense in cutting cold metals partially solved by the introduction of high-speed cutting machines requiring from forty to seventy-five horse-power. These machines, while reducing the actual cutting time to the minimum, have not come into very general use for three reasons: first, the original cost of machine is too great for ordinary requirements; second, the excessive high speed tends to seriously disturb the temper of the metal, and leaves burs on the work, requiring special hand-trimming in order to complete same; and third, the size and weight of the machines preclude the possibility of easy transportation to different parts of machine shops and yards, or for use in railroad section work.



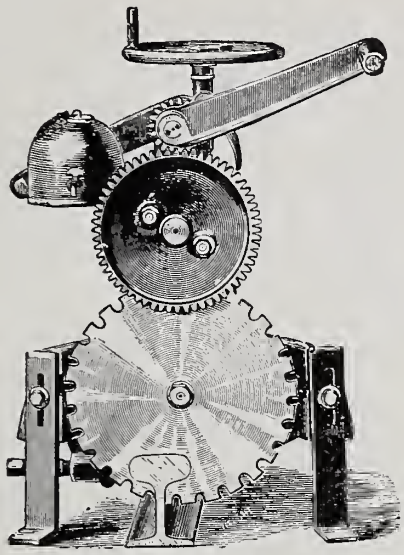
It remained to bring out and develop a machine adapted to a very large range of work, possessing the desirable features of the high-speed and heavy horse-power machines, overcoming many of the objections which obtained in the more expensive machines, and at the same time a machine which could be sold at a very reasonable price.



This result has been obtained by the Bryant system of saws, chiefly by the employment of a new principle of applying the power directly to the saw blade on its periphery, whereby the very best results can be obtained by slow

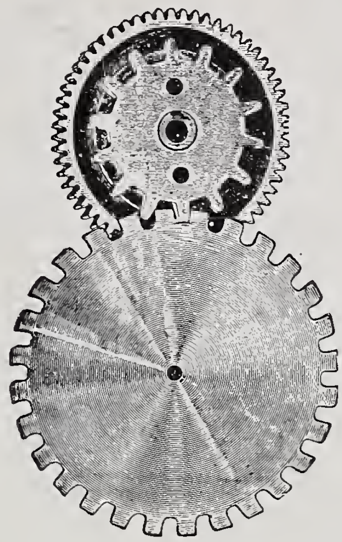
motion and the minimum power. These saws are made both portable and stationary.

The portable machine requires very small space, weighs but 221 pounds, can be easily operated by two men, and will cut a street or steam rail in less than ten minutes. The manufacturers have



record of a sixty-pound rail cut in three minutes, and a seventy-two-pound rail on a thirty-five-degree angle in seven minutes.

The stationary machine, in doing its heaviest work, requires about one horse-power, and will cut a fifteen-inch "I" beam straight in six minutes. Equally rapid work at any angle can be performed on either machine. One of the peculiar features of the Bryant saw is the construction of the tooth, being such that each tooth acts as a planing cutter, insuring a very much larger amount of work in any given time, leaving each true and smooth without disturbing the temper of the



metal. Accuracy to $\frac{1}{100}$ of an inch is claimed. The speed is limited to seven turns per minute.

The accompanying illustrations show the No. 1 portable machine and the No. 10 power machine, together with a few samples of the work done on them. These machines are manufactured by the Q. & C. Company, of Chicago.

Reflections and Observations.

Edison was born in a little town in Ohio, which isn't much larger now than when he first saw the light of the world.

One day a stranger came to this town, and thought he would pay a pilgrimage to the birthplace of this eminent inventor.

"Where was it," he asked one of the townsmen, "that Edison formerly lived?"

"Who's Edison?" asked the old settler.

"Why, don't you know the Edison, the great Edison?"

"What was his first name?"

"Thomas," replied the stranger.

"Oh, yes; there yuseter be a man by that name live here, but he went off a good many years ago. He don't amount to much though, as far as I can learn; just spends all his time trying to get up new-fangled notions."

++

Some people have queer ideas of justice. About a year ago an engineer brought an injector to a machine shop for repairs.

He didn't ask what it would cost, and when the injector was returned with the bill for five dollars he "kicked hard."

Some months went by, but the bill remained unpaid. After making every effort to effect a settlement, the machinist placed his account in the hands of a lawyer.

The next day the engineer went to his lawyer and said: "That fool of a machinist has gone to work and sued me for five dollars."

"Well, you owe it, don't you?" asked the lawyer.

"I suppose I do; but he has gone and sued me! sued me!"

"Then, why don't you pay him, if you owe him?"

"Because he's sued me; and when a man does *that*, I'll never pay him till it costs him more than he gets. I want you to make it cost him all you can."

"But it will cost you something too."

"I don't care for that. What do you charge to begin with?"

"Ten dollars; and more if there is much extra trouble."

"All right! There's the X. Now go ahead!"

No sooner was his client gone than the lawyer stepped across to the machinist, Smith, and offered to pay the bill, on condition that the suit should be withdrawn. The machinist gladly acceded—all he wanted was his pay. The lawyer retained the other five for his fee, and as the case was not "troublesome" made no further demands upon his client.

Ten days after, Jones, the engineer, came in to see how his case was getting on.

"All right!" said the lawyer. "You won't have any trouble about that. I put it to Smith so strongly that he was glad to withdraw the suit altogether."

"Capital!" cried the exulting Jones. "You've done it up brown! You shall have all my business."

++

An engineer who was of a religious turn of mind, and who had been reading the Bible considerably, was a little in doubt as to what a miracle really was. He was not a "fool of an engineer," as they say, but one of those men who had an inquiring spirit and who had his doubts upon certain theological points.

The steam plant of which he had charge consisted of a hundred horsepower Corliss engine, and was considered one of the finest in the town, which was a small manufacturing center in Vermont.

Some few weeks before the Baptist

church had been without a pastor, and had found it rather difficult to obtain one.

One day a stranger in the garb somewhat resembling a clergyman came into town, and some of the deacons inquired if he knew of a suitable person.

"Why, I will accept the position myself," he replied.

Without any hesitancy a special meeting of the deacons was called, and the stranger took charge of the church.

A few days afterwards the engineer who wanted to know about miracles, seeing him pass, called him into his engine room.

"What do you want?" asked the minister.

"If you please, sir, I want you to explain to me what a miracle is like. I can't quite make it out."

"You can't, eh? Well, just step up near your engine there, and I will show you."

The engineer went up to his engine and stood by its side for a few minutes. The minister remained at the end of the room rummaging about some old iron. Suddenly he picked out a piece of heavy shafting, and before the engineer could divine his purpose placed it in such a position near the eccentric that with the next revolution the engine was smashed to pieces, while the engineer and the minister lay on the floor badly injured.

In a few moments the minister crept slyly up to the engineer and said: "Smashed it all to pieces, didn't it?"

"Yes," feebly responded the dying engineer.

"The piece of fly-wheel hurt you pretty bad, didn't it?"

"Yes," answered the almost unconscious man.

"Well, my man," said the minister, "if that piece of iron hadn't smashed the engine, and the piece that hit you hadn't hurt you, it would have been a miracle."

It might be added that it was soon after discovered that the minister was an escaped lunatic.

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DURING the past twenty-five years we have heard from time to time that Keeley's motor would soon mote.

We have been told that perpendicular power exerted in an oblique direction would be enlarged sixteen million times if it could be expanded horizontally, or some similar nonsense like this.

Meanwhile, Mr. Keeley has lived and grown fat, and it might likewise be added gray, at the expense of those who are hoping to see his ethereal force, in comparison to which dynamite is but a plaything.

Not long ago one of Mr. Keeley's admirers had a portrait of the inventor painted, which for a while was exhibited in a Philadelphia store. It represented Mr. Keeley standing full length, one hand leaning upon a table and the other in his pocket.

From time to time different people stopped, looked at the picture, and made some remark. A lady, who evidently knew him, was looking in the window where the picture was exhibited, when a gentleman stopped to do likewise.

"Isn't that just like him?" she remarked.

"No, madam, I don't think it's a bit like him."

"Well, where do you think it lacks perfection?" asked the lady.

"Well, it isn't like him a bit," replied the man.

"Do you know him?"

"No, I never saw him in my life."

"Well, then, why do you say this picture is bad?"

"That's easy enough. The picture shows him, as you will notice, with his hand in his own pocket. If it represented him with his hand in somebody else's pocket it would be a perfect likeness of him."

++

A TRAVELING salesman connected with a mining machinery concern in Chicago recently met an Englishman up in Nevada who evidently had been badly bitten by the mining sharks who are always looking out for victims. The salesman in question, in conversation with The Observer, said: "As you know, strangers as well as old settlers are sometimes taken in and robbed in the most barefaced manner by buying claims which have been 'salted.' These claims, as Edison remarked a few days

ago about gold in the south, are all 'samples.' Well," went on the drummer, as the train sped along, "I asked the man what his business was, and he replied: 'Prospecting.' Thinking I could make a sale of our improved mining machinery to him, I commenced to tell him of the great opportunities that existed in Nevada and Idaho.

"'Is that so?' he replied, when I lost my breath and gave him an opportunity of putting in a word. 'I've just come from Nevada, and you couldn't sell me a steam engine or a diamond drill if you would let me have them for a dollar apiece. I went out there with lots of money; I have my bag full of "salt." That's all I have left. I will tell you,' he continued, 'what you Americans ought to do, or the authorities out in Nevada should.'

"'What's that?' inquired the drummer.

"'Well, you ought to adopt the Irish flag as the coat-of-arms for the state.'

"'Why should we do that?'

"'Because,' replied the prospector, 'as far as my experience has shown me, the true symbol of their coat-of-arms should be a shamrock and a lyre.'"

THE decision just rendered substantiating Edison's claim to the patent as the inventor of the electric light, after twelve years of litigation, brings to mind the story of an inventor and a lawyer which the writer heard the other day.

It seems that there had been an infringement upon the inventor's patent by a wealthy company which, having ability to produce the patented article at a lower price than the originator, had flooded the market with the goods so that the inventor was made nearly a bankrupt. An injunction was obtained, but the company compromised by paying the plaintiff $1000. In several suits that had taken place previously, the plaintiff, who was a bright, sprightly man, seemed to give the jury the impression that he was a man of wealth. During the last trial his attorney thought a little acting would be of advantage, so at a proper moment when he referred to the patentee as a man who had had his rights wrested from him, and who, as the jury could see, was then plunged into deep despair, he was instructed to shed tears, and after considerable effort the moisture began to drop from his eyes.

As has been stated, the case was decided in his favor, and he returned with his attorney to the latter's office. The lawyer quickly made out his bill for services rendered, and the inventor saw that it was within fifty dollars of the amount just received from the defendant.

The next day an engineer who had been present at the trial met the attorney and said to him: "You understand your business, don't you? But those weren't real tears that your client shed yesterday."

"How do you know?" asked the lawyer.

"Well, you see, I passed your office just as you handed him your bill, and there was a big difference between his tears when he gave you the money he had just received and those he had shed in court."

THE OBSERVER.